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Billie H. Hix
BILLIE H. HIX
Chief, Technical Systems Branch
The Albert F. Simpson Historical Research Center

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SECRET-SWARMER-SECRET

HEADQUARTERS
TASK FORCE AIR FORCE
POPE AIR FORCE BASE
FORT BRAGG
NORTH CAROLINA

Operation Plan
TFAF No. 3-50

EXERCISE SWARMER

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Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, NC
13 March 1950

Operation Plan
TFAF No. 3-50

Chart and Map References:
See Annex C, Intelligence.

Task Organization:
See Annex A, Task Organization and Command Relationships.

Task Force Air Force	Brig Gen Wolfinbarger
161st Tactical Reconnaissance Sq	
Dets 1850th AACS Mobile Comm Sq	
Dets 2060th Mobile Weather Sq	
Tactical Air Force (Prov)	Brig Gen Wolfinbarger
4th Fighter-Interceptor Wg	
20th Fighter-Bomber Wg	
502d Tactical Control Gp	
934th Signal Battalion (Sep) TAC	
4th Liaison Flight	
Troop Carrier Force	Col Prindle
314th Troop Carrier Wg	
62d Troop Carrier Wg (1 Sq)	
MATS Unit	
Tactical Bomber Force	Col Chapman
84th Bomb Sq (L) Jet	
85th Bomb Sq (L) Jet	

1. General Situation: AGGRESSOR established bases in the CARIBBEAN in the fall of 1946 and since that time has launched several attacks against the UNITED STATES with varying degrees of success. The tempo of AGGRESSOR air missions over the FLORIDA Peninsula and the southeastern areas of the UNITED STATES has been increased. On 1 February 1950, AGGRESSOR dropped powerful bombs on JACKSONVILLE and MIAMI. Following this, leaflets were dropped on all principal cities of FLORIDA announcing a forthcoming invasion and threatening that any resistance or demolition of military installations would result in further retaliatory action. Beginning 2 February 1950, AGGRESSOR 1st Airborne Corps assaulted centeral FLORIDA, secured airfields, and moved northward to contact UNITED STATES Forces. Between 5 and 15 February, AGGRESSOR landed one rifle corps (two rifle divisions and one tank division) to relieve the 1st Airborne Corps which was then assembled at principal airfields in central FLORIDA, with the Corps Headquarters at ORLANDO. By the end of February, AGGRESSOR consolidated the general line JACKSONVILLE-TALLAHASSEE-APALACHICOLA. On 10 March 1950, an AGGRESSOR submarine assault resulted in the capture of WILMINGTON, NORTH CAROLINA. At the same time AGGRESSOR seized the FORT BRAGG-CAMP MACKALL-FAYETTEVILLE area by air assault, and is now enlarging and expanding his airhead.

a. Enemy Forces: (See Annex C, Intelligence)

(1) AGGRESSOR 1st Airborne Corps occupies the airhead in the FORT BRAGG-CAMP MACKALL-FAYETTEVILLE area. This corps constitutes the only known AGGRESSOR Airborne troops in the Theater.

(2) AGGRESSOR has sufficient aircraft to support a corps airhead.

(3) AGGRESSOR Capabilities:

(a) Air transporting 21,504 troops with equipment, or5,040 tons of materiel, a combat radius of 850 nautical miles from advance bases in the ORLANDO area.

(b) Conducting daily photographic reconnaissance a distance of 250 miles inland from the NORTH CAROLINA coast.

b. Friendly Forces:

(1) The Southeastern Theater (SET), with Headquarters in ATLANTA, GEORGIA, is responsible for the security of the southeastern UNITED STATES. Operating under SET, the Third Army is charged with security of the area: FLORIDA, GEORGIA, ALABAMA, MISSISSIPPI, SOUTH CAROLINA, NORTH CAROLINA, and TENNESSEE.

(2) The Third Army, composed of the V, X, XI and XII Corps, has the mission of defending the Gulf coast from the MISSISSIPPI-LOUISIANA Boundary to ELIZABETH CITY, NORTH CAROLINA.

(3) V Corps is charged with the destruction of AGGRESSOR units in NORTH CAROLINA. To accomplish the destruction of these AGGRESSOR units, an airborne operation will be conducted in the FORT BRAGG-FAYETTEVILLE-CAMP MACKALL-POPE AIR FORCE BASE area. Due to extended frontages of the UNITED STATES Forces containing AGGRESSOR in this area, the forces under V Corps must be reinforced and supplied indefinitely by air. For this operation, V Corps will be composed of the 82d Airborne Division, the 11th Airborne Division, and the 3d Infantry Division, (CPX).

(4) Carolina Base Section provides administrative and logistical support for V Corps; operates the required aerial ports of embarkation and debarkation during during build-up of the airhead; calls forward and transports troops and materiel of TFAF and V Corps through the departure and airhead bases.

c. Assumptions: Omitted.

2. Missions:

a. This force will:

(1) Conduct troop carrier, and other combat air operations, consisting of counter-air, interdiction, tactical and photographic reconnaissance, close support, and air defense in order to:

(a) Gain and Maintain air superiority.

(b) Interdict AGGRESSOR movement in the FORT BRAGG-FAYETTEVILLE-CAMP MACKALL-POPE AIR FORCE BASE area.

(c) Furnish necessary airlift for such paradrop, aerial resupply, and air landing missions required to establish and supply a corps-size airhead.

(d) Provide the tactical air support required for consolidation and expansion of the airhead.

3. Tasks for Subordinate Units:

a. Troop Carrier Force MAXTON AIRBASE, NC will provide the airlift necessary to initiate a corps-size airhead on D-Day and accomplish the subsequent airhead build-up from D-Day through D+10.

(1) The 314th Troop Carrier Wing will:

(a) Move to MAXTON AIRBASE, NORTH CAROLINA, with the 314th and the 316th Troop Carrier Groups and necessary supporting elements of the wing.

(b) Set up and operate a base operations office at MAXTON AIRBASE in accordance with AFR 20-47.

(c) Airlift personnel and equipment as directed by Headquarters, Troop Carrier Force.

(d) Stage an airborne operation on D-Day from designated bases; air drop and air land regimental combat teams in the objective area as directed by Headquarters, Troop Carrier Force.

(e) Accomplish resupply missions as directed by Headquarters, Troop Carrier Force after establishing the airhead.

(f) Accomplish evacuation missions as directed by Headquarters, Troop Carrier Force.

(2) The 62d Troop Carrier Wing (1 Squadron) will:

(a) Move one (1) Troop Carrier Squadron, with necessary supporting elements, to SHAW AIR FORCE BASE, S.C.

(b) Airlift personnel and equipment as directed by Headquarters, Troop Carrier Force.

(c) Accomplish evacuation missions as directed by Headquarters, Troop Carrier Force.

(3) The Military Air Transport Service will:

(a) Furnish one hundred (100) C-54 aircraft to arrive at CONGAREE AIRBASE, SOUTH CAROLINA, by 23 April 1950 to airlift personnel, supplies, and equipment as directed by the Commanding Officer, Troop Carrier Force.

b. The Tactical Bomber Force (2 Squadrons B-45's) at LANGLEY AIR FORCE BASE, VA, will execute counter-air and interdiction missions as directed by Headquarters, Task Force Air Force.

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c. The Tactical Air Force (Prov), OUTER CAMP MACKALL, N. C., will conduct combat air operations, consisting of counter-air, interdiction, close support, air defense, and support of troop carrier operations.

(1) The 4th Fighter-Interceptor Wing, LANGLEY AIR FORCE BASE, VA., will:

(a) Move the 4th Fighter Group (3 Squadrons F-86 aircraft) with minimum essential supporting elements, from LANGLEY AIR FORCE BASE, VA., to MAXTON AIRBASE, NC, so as to be operational at MAXTON AIRBASE not later than 15 April 1950.

(b) Executecounter-air, close support and air defense missions as directed by Headquarters, Tactical Air Force (Prov).

(2) The 20th Fighter-Bomber Wing (3 Squadrons F-84 aircraft) at SHAW AIR FORCE BASE, SOUTH CAROLINA, will:

(a) Execute counter-air, air defense, interdiction, and close support missions as directed by Headquarters, Tactical Air Force (Prov).

(3) The 502d Tactical Control Group will:

(a) Provide such aircraft control and warning facilities as may be required at the Tactical Air Force CP OUTER CAMP MACKALL, NORTH CAROLINA, and in the vicinity of the maneuver area during the exercise as directed by the Commanding General, Tactical Air Force (Prov), (See Annex F, Communications.)

(b) Provide necessary units (TACP's) to accompany the airborne force to the objective area.

(4) The 934th Signal Battalion (Sep) TAC will:

(a) Provide such terminal communications facilities for Headquarters, TFAF, TAF (Prov) and supporting elements, as may be required at the CP in the OUTER CAMP MACKALL area.

(5) The 4th Liaison Flight will:

(a) Move to maneuver bases as directed by the Maneuver Commander.

(b) Provide necessary aircraft for the accomplishment of administrative flights as directed by Headquarters, Tactical Air Force (Prov).

d. The 161st Tactical Reconnaissance Squadron (1 Squadron RF-80 aircraft) at SHAW AIR FORCE BASE, SOUTH CAROLINA will:

(1) Execute reconnaissance (visual and photographic) missions as directed by Headquarters, Task Force Air Force.

e. Dets., 1850th AACS Mobile Comm Sq, will furnish tower and communications service as directed by Headquarters, Task Force Air Force.

f. Dets., 2060th Mobile Weather Sq. will furnish weather service as directed by Headquarters, Task Force Air Force

x. (1) Commanding Officers of all maneuver air bases (excluding LANGLEY AIR FORCE BASE, VA.,) will prepare base Defense Plans and forward one (1) copy to Headquarters, Task Force Air Force by 18 April 1950.

(2) All organizations will conduct unit training in preparation for participating in Exercise SWARMER prior to departure from home stations. Units operating from home stations will complete this training prior to 15 April 1950.

(3) All Air Force Units will return to home stations so as to arrive not later than 2400 hours 14 May 1950.

(4) This plan is effective for planning upon receipt, and for execution on direction from Headquarters, Task Force Air Force.

4. Administrative and Logistical Matters: See Annex I, Administrative Plan.

5. Command and Signal Matters:

a. Command. See Annex A, Task Organization and Command Relationships.

b. Signal. See Annex F, Communications.

Chester L. Sluder
CHESTER L. SLUDER
Colonel USAF

Annexes:

A - Task Organization and Command Relationships

B - General Concept and Scheme of Maneuver

C - Intelligence

D - Air Employment Plan

E - Troop Carrier Plan

F - Communications Plan

G - Meteorological Plan

H - Special Weapons Defense Plan (To be published)

I - Administrative Plan

J - Public Information (To be published)

K - Reports

DISTRIBUTION: See Distribution List.

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CG, Tactical Bomber Force (CO, 363d Tactical Reconnaissance Gp) Langley AFB, Va	5 cys
CG, 314th Troop Carrier Wg, Smyrna AFB, Tenn	20 cys
CG, 20th Ftr-Bomber Wg, Shaw AFB, SC	10 cys
CG, 62d Troop Carrier Wg, McChord AFB, Wash	3 cys
CO, 161st Tac Rcn Sq, Shaw AFB, SC	2 cys
CO, 502d Tactical Control Gp, Pope AFB, NC	3 cys
CO, 934th Signal Bn (Sep) TAC, Pope AFB, NC	3 cys
CO, 4th Liaison Flt, Pope AFB, NC	2 cys
CO, 2060th Mobile Weather Sq, Tinker AFB, Okla	1 cy
CO, 1850th AACS Mobile Comm Sq, Tinker AFB, Okla	1 cy
Chief, Air Weather Service, Andrews AFB, Md	2 cys

Info cys to:

CG, ManCom SWARMER, Fort Bragg, NC	5 cys
CG, ConAC, Mitchel AFB, NY	5 cys
CG, TAC, Langley AFB, Va	5 cys
CG, 14th AF, Robins AFB, Ga	5 cys
CG, 4th AF, Hamilton AFB, Calif	2 cys
CG, 9th AF, Langley AFB, Va	2 cys
CG, 2d Army, Fort George C. Meade, Md.	3 cys
CG, 3d Army, Fort McPherson, Ga	3 cys
CG, V Corps, Fort Bragg, NC	2 cys
CG, 82d Abn Div, Fort Bragg, NC	3 cys
CG, 11th Abn Div, Camp Campbell, Ky	3 cys
CG, 3d Inf Div, Fort Benning, Ga	1 cy

HEADQUARTERS

TASK FORCE AIR FORCE

EXERCISE SWARMER

POPE AIR FORCE BASE

FORT BRAGG, NORTH CAROLINA

OPERATION PLAN
TFAF No. 3-50

ANNEX A

TASK ORGANIZATION AND COMMAND RELATIONSHIPS

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Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

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ANNEX A

TASK ORGANIZATION AND COMMAND RELATIONSHIPS

Hq, Task Force Air Force	Brig Gen	Wolfinbarger
161st Tactical Rcn Sq	Lt Col	Jackson
AWS Detachments	Major	Throckmorton
AACS Detachments	Captain	Parrish
Hq, TAF (Prov)	Brig Gen	Wolfinbarger
4th Ftr-Intcpt Wg	Colonel	Smith
20th Ftr-Bmr Wg	Colonel	Morrill
4th Liaison Flt	Captain	Hicks
502d Tac Control Gp	Lt Col	Logan
934th Signal Bn (Sep) TAC	Lt Col	Maersch
Troop Carrier Force	Colonel	Prindle
314th Tr Carr Wg	Colonel	Prindle
MATS		
62d Tr Carr Wg (1 Sq)		
Tactical Bomber Force	Colonel	Chapman
85th Bmb Sq (L) Jet	Lt Col	Willis
84th Bmb Sq (L) Jet	Major	Thabault

Chester L. Sluder
CHESTER L. SLUDER
Colonel USAF

Appendices:

I - Designation of Command Posts and Stations
II - Organization of Task Force Air Force
III - Organization of Southeastern Theater 1 April 1950

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Operation Plan.
TFAF No. 3-50

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

APPENDIX I TO ANNEX A

DESIGNATION OF COMMAND POSTS AND STATIONS

UNIT	COMMAND POST	COORDINATES	OPERATIONAL READINESS DATE	HOME STATION
Hq, Task Force Air Force	OUTER CAMP MACKALL, N.C.	Lat 34° 59'N Long 79° 34'W	0001 15 April 1950	- - - - - - -
161st Tac Rcn Wg	SHAW AFB, S. C.	Lat 33° 58'N Long 80° 28'W	0001 15 April 1950	SHAW AFB, S. C.
AWS Detachments	MACKALL AIRBASE, N.C.	Lat 35° 02'N Long 79° 30'W	0001 15 April 1950	TINKER AFB, OKLA
Sub-Dets: MAXTON AIRBASE CONGAREE AIRBASE				
AACS Detachments	MACKALL AIRBASE, N.C.	Lat 35° 02'N Long 79° 30'W	0001 15 April 1950	TINKER AFB, OKLA
Sub-Dets: MAXTON AIRBASE CONGAREE AIRBASE				
Hq, TAF (Prov)	OUTER CAMP MACKALL, N.C.	Lat 34° 59'N Long 79° 34'W	0001 15 April 1950	POPE AFB, N. C.
4th Ftr-Incpt Wg	MAXTON AIRBASE, N.C.	Lat 34° 47'N Long 79° 23'W	0001 15 April 1950	LANGLEY AFB, VA.
20th Ftr-Bmr Wg	SHAW AFB, S.C.	Lat 33° 58'N Long 80° 28'W	0001 15 April 1950	SHAW AFB, S. C.
4th Liaison Flt	OUTER CAMP MACKALL, N.C.	Lat 34° 59'N Long 79° 34'W	0001 15 April 1950	POPE AFB, N. C.
502d Tac Control Gp	OUTER CAMP MACKALL, N.C.	Lat 34° 59'N Long 79° 34'W	0001 15 April 1950	POPE AFB, N. C.

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UNIT	COMMAND POST	COORDINATES	OPERATIONAL READINESS DATE	HOME STATION
934th Sig Bn (Sep) TAC	OUTER CAMP MACKALL N.C.	Lat 34° 59'N Long 79° 34'W	0001 15 April 1950	POPE AFB, N. C.
Troop Carrier Force	MAXTON AIRBASE, N.C.	Lat 34° 47'N Long 79° 23'W	0001 15 April 1950	- - - - - - - - -
314th Tr Carr Wg	MAXTON AIRBASE, N.C.	Lat 34° 47'N Long 79° 23'W	0001 15 April 1950	SMYRNA AFB, TENN.
MATS	CONGAREE AIRBASE, S.C.	Lat 33° 56'N Long 80° 48'W	0001 23 April 1950	- - - - - - - - -
62d Tr Carr Wg (1 Sq)	SHAW AFB, S. C.	Lat 33° 58'N Long 80° 28'W	(0001 15 April 1950)	MCCHORD AFB, WASH.
Tactical Bomber Force	LANGLEY AFB, VA.	Lat 37° 05'N Long 76° 21'W	0001 15 April 1950	- - - - - - - - -
85th Bmb Sq (L) Jet	LANGLEY AFB, VA		0001 15 April 1950	LANGLEY AFB, VA.
84th Bmb Sq (L) Jet	LANGLEY AFB, VA		0001 15 April 1950	LANGLEY AFB, VA

Authenticated:

Lattie A. Ritter Jr. (signature)
LATTIE A. RITTER JR.
Major, USAF
Actg Deputy for P&R

CHESTER L. SLUDER
Colonel, USAF

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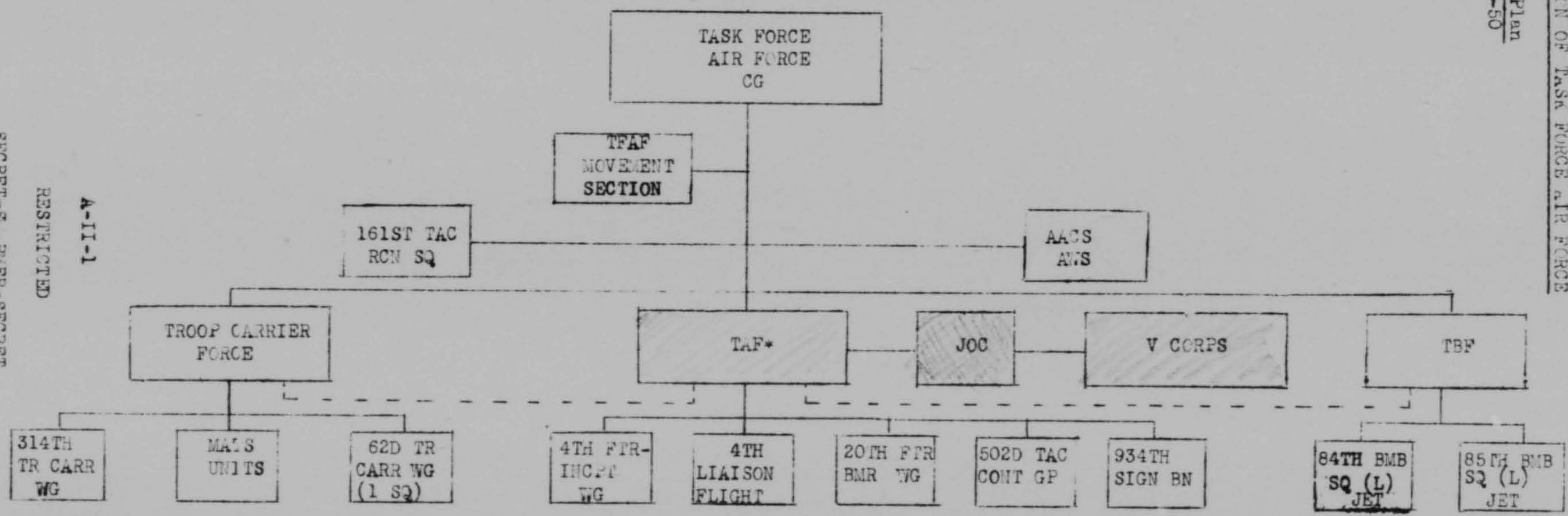
Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, NC
13 March 1950

APPENDIX II TO ANNEX A
ORGANIZATION OF TASK FORCE AIR FORCE

Operation Plan
TFAF No. 3-50

APPENDIX II TO ANNEX A

ORGANIZATION OF TASK FORCE AIR FORCE



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LATTIE A. RITTER, Jr
Major USAF

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APPENDIX III TO ANNEX A
ORGANIZATION OF SOUTHEASTERN THEATRE 1 APRIL 1950

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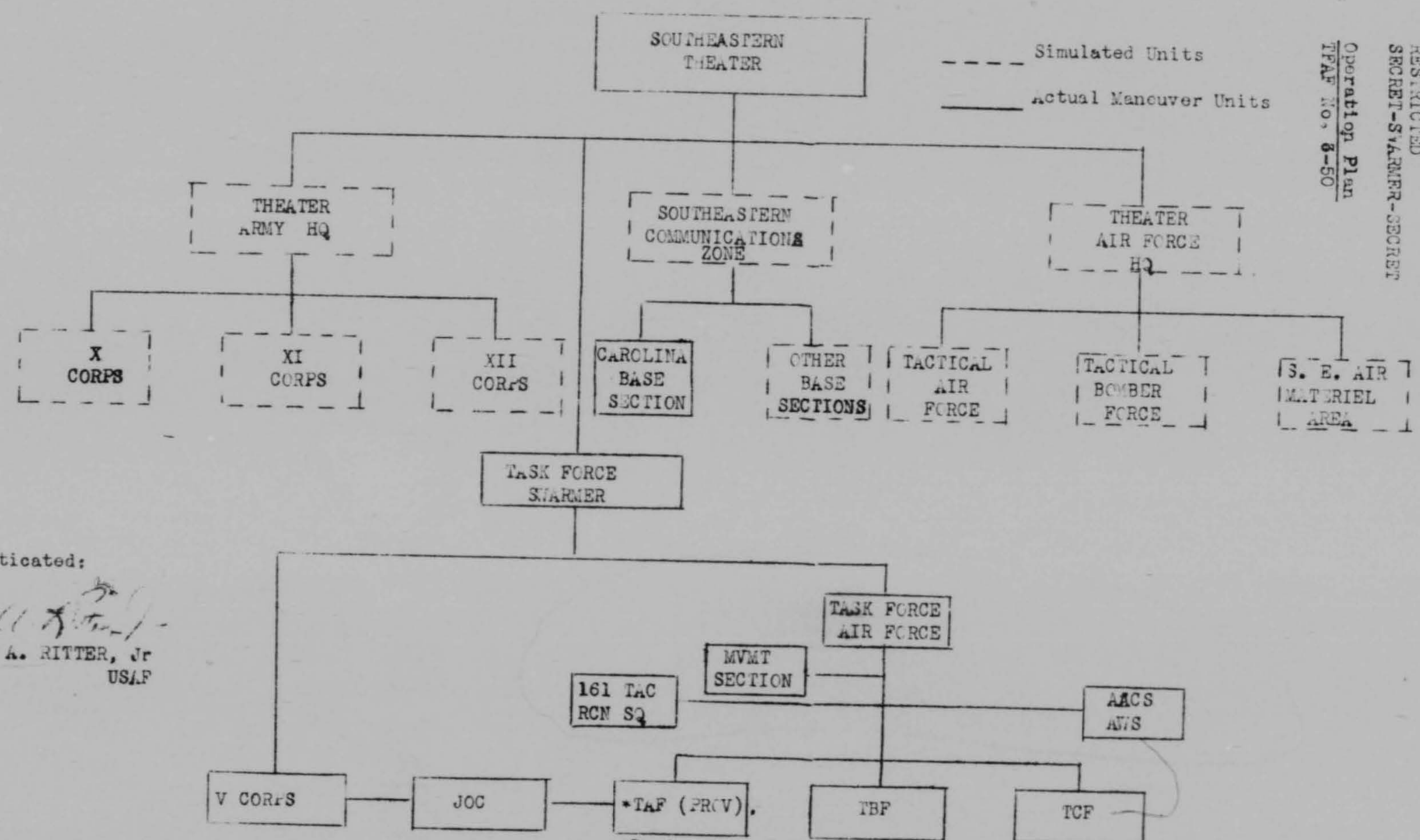
Operation Plan
TFAF No. 8-50

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, NC
13 March 1950

ORGANIZATION OF SOUTHEASTERN THEATER 1 April 1950



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HEADQUARTERS
TASK FORCE AIR FORCE
EXERCISE SWARMER
POPE AIR FORCE BASE
FORT BRAGG, NORTH CAROLINA

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ANNEX B

GENERAL CONCEPT AND SCHEME OF MANEUVER

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Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
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ANNEX B

GENERAL CONCEPT AND SCHEME OF MANEUVER

1. Accomplishment of Tasks.

a. The mission of Task Force Air Force in Exercise SWARMER is to reconnoiter, neutralize and destroy enemy air and ground forces, and their installations, in support of the airborne assault and subsequent operations; transport the airborne troops to the objective area and provide tactical air support throughout the maneuver; conduct continuous airlift of supplies and equipment to support the airhead; gain and maintain the required degree of air superiority prior to and after the establishment of the corps airhead; and be prepared to conduct such other operations as may be directed by the Commander, Task Force SWARMER for expanding the airhead.

b. Air superiority will be mandatory on and subsequent to D-Day to afford United States troops freedom of movement. Prompt processing of air requests by the Joint Operations Center and efficient dispatching of aircraft by the Combat Operations Section are necessary to insure maximum support of the ground force troops.

c. Maneuver bases are specified in Annex A, Task Organization and Command Relationships.

2. Phases of Accomplishment.

a. Supporting Operations of Friendly Forces.

(1) See Annex C, Intelligence.

b. Preliminary Operations.

(1) Prior to 15 April 1950, Air Force units will receive suitable unit training to prepare them for their operations in Exercise SWARMER. The parent Air Force will be responsible for the conduct of this training.

(2) Movement of units will be as specified in Annex I, Administrative Plan.

(3) After arrival of the units at assigned maneuver bases, or after 15 April 1950 for units operating from home bases, Commanding General, Task Force Air Force will prescribe unit training to be conducted until 21 April 1950. (See Annex D, Air Employment Plan.)

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c. The Assault.

(1) Commencing 15 April 1950, photo reconnaissance missions of the objective area will begin, and will continue throughout the maneuver.

(2) On 21 April 1950, Air Force units will conduct:

(a) Initial Counter Air Operations.

1 Recon, visual and photo

2 Fighter-bomber operations against enemy airfields and aircraft.

3 Fighter sweeps.

4 Tactical bomber attacks on enemy airfields, control installations, fuel storage dumps, maintenance shops, hangars, etc.

(b) Interdiction.

1 Recon, visual and photo.

2 Attacks against land lines of communications, bridges, choke points, rail marshalling yards, etc.

3 Attacks on troop movements and concentrations.

(c) Air Defense (Concurrent with all phases of operations.)

1 Controlled intercept missions.

a Air alert

b Ground alert

2 At the discretion of the Commanding General, Task Force Air Force, a predetermined portion of available fighter aircraft will be allocated for air defense throughout the maneuver. Exact allocation will depend upon the tactical situation.

3 The aircraft control and warning net will be established by the 502d Tactical Control Group, not later than 15 April 1950. This net will consist basically of standard air control and warning facilities.

(3) Commencing on or about 24 April 1950, a continuous corps airhead maneuver against AGGRESSOR will begin, in which the Task Force Air Force will conduct:

(a) Counter Air Operations.

1 Same as 2.c.(2) (a) above.

2 Continuous Combat Air Patrol (CAP) over objective area on D-Day.

3 Flak-suppression missions as required.

(b) Interdiction.

1 Same as 2.c.(2) (b) above.

(c) Ground Support.

1 Conduct such close support missions as may be directed.

(d) Airborne Operations.

1 On D-Day, the Troop Carrier Force, escorted by Tactical Air Force (Prov), will airlift four (4) Regimental Teams (RCT's) to be dropped in the objective area, and one (1) RCT to be airlanded at MACKALL AIRBASE after its capture.

2 Troop Carrier Force will provide continuous airlift for buildup of the airhead from D-Day until the end of the maneuver (Simulate an indefinite period.)

3. Development of the Objective.

a. Following the airborne assault of the objective area, and the capture of MACKALL AIRBASE, the movement of Task Force Air Force units into the airhead through D/10 will be as follows:

Hq, Task Force Air Force (Adv) (Simulated)

4th Ftr-Interceptor Wing (Simulated)

161st Tac Rcn Squadron (Simulated)

502d Tactical Control Group Detachments

b. Due to limitations of facilities, no Air Force units except TaCP's and designated elements of the 502d Tactical Control Group will actually go into the airhead. Other movement will be simulated.

4. Coordination and Command Relationship.

a. Coordination.

(1) Liaison Officers to the 82d and 11th Airborne Divisions will be supplied by the Troop Carrier Force to coordinate details for airlift of these units.

b. Command Relationships.

(1) See Annex A, Task Organization and Command Relationships.

Chester L. Sluder

CHESTER L. SLUDER
Colonel USAF

HEADQUARTERS
TASK FORCE AIR FORCE
POPE AIR FORCE BASE
FORT BRAGG, NORTH CAROLINA

OPERATION PLAN
TFAF No. 3-50

ANNEX C

INTELLIGENCE

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Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N. C.
13 March 1950

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ANNEX C

INTELLIGENCE

Map References: US Army Areas, AMS 8301, Scale 1:1,000,000
665494 NEW ORLEANS # 10 and 665495 SAVANNAH # 11.

World Aeronautical Charts 357, 358, 359, 409 and 410.

PART I - INTELLIGENCE SUMMARY

1. Summary of Enemy Situation:

a. Reference

(1) Departments of the Air Force and Army, "Directive for Joint (Army-Air Force) Exercise FY 1950", 10 December 1949.

(2) General Plan for Training Exercise SWARMER, Hq Maneuver Commander Exercise SWARMER, dated 17 Feb 50. File C 354.

b. General

(1) A state of undeclared war exists between the UNITED STATES and AGGRESSOR. The ambition of the AGGRESSOR nation is to establish itself as the most powerful nation on earth, and then by military means, to maintain such position. To achieve these objectives, the AGGRESSOR Supreme Council early appreciated the fact that the UNITED STATES must be defeated and forced to become an AGGRESSOR satellite. Then with this war potential and resources, AGGRESSOR plans to subjugate the rest of the world. Consequently, AGGRESSOR launched his first attack against the UNITED STATES in November 1946. Subsequently, AGGRESSOR has launched several attacks against the UNITED STATES with varying success.

(2) In all of the campaigns against the UNITED STATES, AGGRESSOR forces have proved to be worthy military opponents. Their leadership has been superior. Their organization, equipment, and tactical doctrine, though distinctly foreign, have been excellent. The discipline and morale of their troops have been high. AGGRESSOR Forces have proved capable of attacking, defending, withdrawing and fighting delaying actions. In addition they have proved to be capable guerilla fighters.

(3) The AGGRESSOR Fourth Army, which has occupied AGGRESSOR CARIBBEAN bases since the fall of 1946 and launched several attacks against the SOUTHEASTERN UNITED STATES, has been replaced by the AGGRESSOR Second Army and has received training in air transportability. Selected units have received amphibious training.

(4) Early in the fall of 1949, AGGRESSOR began concentrating transport, cargo ships, tankers and auxiliary craft at the principal island ports. Increased naval craft and air force planes were reported in the CARIBBEAN area. In January the tempo of AGGRESSOR air missions over the FLORIDA PENINSULA and the SOUTH-EASTERN AREAS OF THE UNITED STATES were stepped up. On 1 February 1950 AGGRESSOR simultaneously dropped powerful bombs on JACKSONVILLE and MIAMI. Following the drop of the bombs AGGRESSOR covered all the principal cities of FLORIDA with leaflets which notified the civilian and military personnel that he intended to occupy FLORIDA and that any resistance or demolition of military installations would result in the dropping of more bombs or other retaliatory action. On 2 February 1950 AGGRESSOR dropped the First Airborne Corps in CENTRAL FLORIDA, quickly secured the airfields and then moved rapidly to the north to contact UNITED STATES Forces. On 5 February AGGRESSOR began to land a Rifle Corps consisting of two Rifle Divisions and one Tank Division minus. By 15 February this corps relieved the First Airborne Corps which was then assembled at principal airfields in CENTRAL FLORIDA with the Corps Headquarters at ORLANDO. By the end of February AGGRESSOR consolidated the general line JACKSONVILLE - TALLAHASSEE - APPALACHICOLA. Intelligence reports indicated that AGGRESSOR planned to attack in NORTH CAROLINA with the primary mission of seizing the WINSTON - SALEM industrial area. Consequently on 10 March 1950, AGGRESSOR seized WILMINGTON, N. C. by a submarine assault assisted by Fifth Columnists and clandestine agents. At the same time AGGRESSOR seized the FORT BRAGG - CAMP MACKALL - FAYETTEVILLE area by air assault. AGGRESSOR is now busily engaged in building up supplies and expanding his airhead.

(5) AGGRESSOR presently has the capabilities of:

(a) Making an airborne assault any place in SOUTHEASTERN UNITED STATES with one airborne corps.

(b) Making an amphibious assault with two divisions, any place on the GULF COAST, or on the ATLANTIC COAST as far north as JACKSONVILLE, FLORIDA.

(c) Making an assault against the SOUTHEASTERN UNITED STATES with any combination of capabilities (5) (a) and (5) (b).

(6) Intelligence reports that AGGRESSOR has a limited stock of powerful bombs. It is considered probable that these bombs will be used without warning.

(7) AGGRESSOR has a large concentration of small commercial vessels. Naval operations are limited to submarine warfare and convoy protection.

(8) AGGRESSOR has developed guided missiles and rockets to a high degree of efficiency. Any concentration of troops or supplies would be a remunerative target.

(9) It can be expected that AGGRESSOR will make full use of well trained agents and sympathizers in operations.

(10) AGGRESSOR has sufficient aircraft to establish and support a Corps airhead.

c. Ground

See paragraph 1 b above.

d. Air

(1) AGGRESSOR has a large well equipped air transport command using cargo type aircraft similar to those used by the UNITED STATES AIR FORCE.

(2) AGGRESSOR has a tactical air force formed along the lines of a modern, efficient air force. The organization of the AGGRESSOR air force is not completely clear but it is known that his tactical air organization generally consists of:

(a) Reconnaissance Regiment

(b) Fighter Regiment

(c) Ground Attack Regiment

(3) In general AGGRESSOR air formation and tactics conform with those of the UNITED STATES AIR FORCE. Equipment is both of conventional and jet type aircraft. Jet fighter-aircraft have been developed to a high degree.

e. Naval

AGGRESSOR naval operations are limited to submarine reconnaissance, submarine warfare, and transport of amphibious forces to operational area by small commercial vessels.

PART II - INTELLIGENCE PRODUCTION

Paragraphs 2, 3, 4 and 5 dealing with Essential Elements of Information, Reconnaissance, Captured Documents and Prisoners of War and Captured Materiel and Souvenirs, respectively, will be published later.

PART III AUXILIARY ACTIVITIES

6. Maps, Charts and Photographs

a. MAPS: The following maps are being prepared by AMS and will be available for Exercise SWARMER:

MAP: US Army Areas, AMS 8301, Scale 1/1,000,000:

665488 CHICAGO #4
665489 PITTSBURG #5
665490 BOSTON #6
665494 NEW ORLEANS #10
665495 SAVANNAH #11

MAP: Topo. FORT BRAGG AND VICINITY NORTH CAROLINA AMS V842, Scale 1/25,000:

600282 OVERHILLS, 5154 II NE
600283 CLIFDALE, 5154 II SE
600284 NICHOLSON CREEK, 5154 II SW
600285 LOBELIA, 5154 II NW
600286 NIAGARA, 5154 III NE
600287 SANATORIUM, 5154 III SE
600288 PINE BLUFF, 5154 III SW
600289 SOUTHERN PINES, 5154 III NW
600290 SLOCOMB, 5254 III NE
600291 VANDER, 5254 III SE
600292 FAYETTEVILLE, 5254 III SW
600293 MANCHESTER, 5254 III NW

(Newly compiled 12 sheets backed up with Photomap, Scale 1/25,000)

PHOTOMAPS: CAMP MACKALL, NORTH CAROLINA, Scale 1/25,000:

116053 SANFORD #19
116055 SANFORD #25
116056 SANFORD #26
116057 SANFORD #31
116058 SANFORD #32
116044 TROY #28
116045 TROY #29
116046 TROY #30
116051 TROY #35
116052 TROY #36
116064 ROCKINGHAM #6
116078 LAURINBURG #1
116079 LAURINBURG #2
116244 LAURINBURG #3

MAP: Topo. FORT BRAGG AND VICINITY, NORTH CAROLINA, Scale 1/50,000 Key Number 100295

The following charts have been requisitioned for Exercise SWARMER:

Regional Aeronautical Charts, Scale 1/1,000,000, Code

WAC 357
WAC 358
WAC 359
WAC 409
WAC 410

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Sectional Aeronautical Charts, Scale 1/500,000, Code APC

Q-8	SAVANNAH	S-7	NASHVILLE
R-8	CHARLOTTE	R-7	CHATTANOOGA
RS-9	NORFOLK	Q-7	BIRMINGHAM
S-8	WINSTON SALEM		

b. Photographs:

Photographic coverage of the maneuver area, when received by this headquarters, will be distributed to air units where applicable.

Request for aerial photographic coverage by air units will conform to the provisions of Appendix 3 to this annex, when published.

c. Distribution:

Distribution of maps, charts and photographs will be made to Air Force units by the Director of Intelligence, Task Force Air Force prior to 15 April 1950. Any subsequent requests for maps or photographs will be placed with the Director of Intelligence, Task Force Air Force.

d. Disposition:

Maps, charts, and photographs, will be returned to the Director of Intelligence, Tactical Air Force (Prov), POPE AIR FORCE BASE, FORT BRAGG, NORTH CAROLINA upon completion of this exercise.

7. SPECIAL INTELLIGENCE

(To be published later)

8. SECURITY:

During preliminary planning stages this exercise will be classified as RESTRICTED. As soon as necessary movement instructions have been issued to units, and on instructions of the Maneuver Commander, security classification will be eliminated. For the play of the exercise, however, SWARMER classifications consistent with the protection required of related documents will be used. These simulated classifications will appear on documents in addition to the classification specified above.

Chester L. Sluder
CHESTER L. SLUDER
Colonel, USAF

Appendices:
- I Intelligence Reports
- II Climatic Study
- III Reconnaissance Plan (To be published later)
- IV Preliminary Estimate of the enemy situation (To be published later)
- V Map of Area of Maneuver (To be published later)
- VI Exercise Historical Reports (To be published later)
- VII Tactical Study of Terrain

RESTRICTED
SECRET-SWARMER-
SECRET

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AFB, FORT BRAGG, N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX I TO ANNEX C

INTELLIGENCE REPORTS

1. REPORTS AND DISTRIBUTION

Air Force Intelligence reports for Exercise "Swarmer" will be prepared and submitted as directed in the following sub-paragraphs:

a. Spot Reports (See Tab "A")

Spot reports will be submitted during the maneuver at the instant of photography, observation, or attack. The most expeditious means of communications available, including voice relay through TACC, will be utilized.

(1) Spot Reports will be submitted during each visual reconnaissance mission. The report will be in a brief narrative form and will include the following information:

(a) Name of report (Spot)

(b) Call word of unit

(c) Where--When--What--Who

(d) Heading or direction of movement

(2) A Spot Report will be submitted following photography of an assigned target or at the moment that it is decided that photography cannot be accomplished. The report will be in brief narrative form and will include the following information:

(a) Name of report (Spot)

(b) Call word of unit

(c) Results of photography (Successful or not)

(d) If not successful, why.

(e) Observations

(3) A Spot Report will be submitted following each attack and will include the following information:

(a) Name of report (Spot)

(b) Call word of unit

(c) Target identity

(d) Type attack

(e) Estimated results

(f) Observations

RESTRICTED
SECRET-SWARMER-SECRET

b. Intelligence Flash Reports (See Tab "B")

An Intelligence Flash Report will be submitted by unit intelligence officers on each mission during the maneuver within one hour after the completion of the mission. It will also be submitted on aborted missions stating the reason for abortion. The Intelligence Flash Report will contain the following information:

(1) Operations order number

(2) Mission number and assignment

(3) Date

(4) Unit designation

(5) Results of mission (Percentage of success or failure with comment)

(6) All observations and activities, including flak, weather, and information submitted as spot reports.

(7) Losses (Personnel and/or equipment), claims and opposition encountered.

c. Mission Intelligence Report: (See Tab "C")

A Mission Intelligence Report will be submitted on each mission within twenty-four (24) hours after completion of the mission and will include the following information:

(1) Operations order number

(2) Date

(3) Unit designation

(4) Name and rank of flight leader

(5) Number and type of aircraft dispatched

(6) Mission assignments

(7) Deviation from assigned route

(8) Landing place, if other than home base

(9) Observations

(a) Troop movements, concentrations and Installations

(b) Airfields

1 Location

2 Number of aircraft

3 Type of aircraft

4 Misc (unit)

(c) Transportation

(d) Miscellaneous

1 Location

2 Heading or direction

3 Number of vehicles

4 Type of vehicles

5 Miscellaneous observations with identification of units if possible

(10) Photography

(a) Location

(b) Altitude

(c) Focal length

(d) Time

(e) Vertical or oblique

(11) Narrative of mission (To include tonnages carried by TC aircraft)

(12) AGGRESSOR opposition encountered

(a) Aircraft

1 Type of aircraft

2 Location

3 Number of aircraft

4 Unit

5 Tactics employed

(b) Flak

1 Type

2 Intensity and accuracy

3 Location

4 Approximate number

(c) Other

(13) Claims

(a) Aircraft

1 Type of aircraft

2 Location

3 Number of aircraft

4 Unit

5 Destroyed or damaged

(b) Transportation

1 Type

2 Number

3 Heading or direction

4 Location

5 Destroyed or damaged

6 Miscellaneous

(c) Other

(14) Losses

(a) Personnel

1 MIA (Missing in action)

2 KIA (Killed in action)

3 WIA (Wounded in action)

(b) Aircraft

1 Destroyed

2 Damaged (Extent)

3 Missing

(15) Remarks

(16) Signature of Intelligence Officer with time filed.

2. TRANSMISSION OF REPORTS:

a. Spot Reports will be transmitted to the TACC by the most expeditious communications facilities available. The TACC will indicate the time the report was received and deliver it to the DIO in the JOC.

b. Flash Reports will be transmitted to the DIO in the JOC by the most expeditious communications facilities available.

c. Mission Intelligence Reports will be transmitted to the DIO in the JOC by the most expeditious communications facilities available.

d. Facilities for reporting purposes may be found in Appendices IV and VI to Annex F, TFAF Operation Plan 3-50.

3. RECORDS:

An Intelligence Journal and work sheet will be maintained by the duty Intelligence Officer in the Joint Operations Center and will be retained for permanent record. See Tab "D".

CHESTER L. SLUDER
Colonel, USAF

4 Tabs:
Tab "A" Spot Report
Tab "B" Intelligence Flash Report
Tab "C" Mission Intelligence Report
Tab "D" Intellignece Journal

Authenticated:
W. E. Howard
W. E. HOWARD
Lt. Col., USAF
Dir Intel

THIS PAGE IS DECLASSIFIED IAW EO 13526

Operation Plan
TFAF No. 3-50

INTELLIGENCE SPOT REPORT

INTELLIGENCE SPOT REPORT

INTELLIGENCE SPOT REPORT

INTELLIGENCE SPOT REPORT

INTELLIGENCE SPOT REPORT

THIS PAGE IS DECLASSIFIED IAW EO 13526

Operation Plan
TFAF No. 3-50

FLASH REPORT

1. Operations Order No.__________________.

2. Mission No. and assignment______________________

3. Date______________

4. Unit Designation______________________________________

5. Results of Mission____________________________________

____

____

6. All observations and activities. (Including information submitted as spot reports).

____

____

7. Losses, claims and opposition encountered:

____

____

____
Intelligence Officer

Operation Plan
TFAF No. 3-50

MISSION INTELLIGENCE REPORT

1. Operations Order number__________ 2. Date__________

3. Unit designation__________

4. Name and rank of flight leader__________

5. Number and type aircraft dispatched on mission__________

6. Mission assignment__________

7. Deviation from assigned routes__________

8. Landing place, if other than home base__________

9. Observations:

a. Troop movements, concentrations, installations__________

b. Airfields__________

c. Transportation__________

d. Miscellaneous__________

10. Photography:

a. Location of Photo	b. Alt	c. F/L	d. Time	e. Vert or Oblique

11. Narrative of mission__________

12. Aggressor opposition encountered:

a. Aircraft__________

Tab "C"

b. Flak________________________________

c. Other________________________________

13. Claims:

a. Aircraft________________________________

b. Transportation________________________________

c. Other________________________________

14. Losses:

a. Personnel:

(1) MIA________________________________

(2) KIA________________________________

(3) WIA________________________________

b. Aircraft:

(1) Destroyed________________________________

(2) Damaged________________________________

(3) Missing________________________________

15. REMARKS________________________________

____
Signature of Intelligence Officer

Tab "C"

Operation Plan
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INTELLIGENCE JOURNAL

ORGANIZATION ____________

FROM ____________

TO ____________

PLACE ____________

Time In	Time Out	Serial No.	Time Dated	Incidents, Messages, Orders, etc	Action Taken

Tab "D"

0039

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE FORT BRAGG N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX II TO ANNEX C

CLIMATIC STUDY

EFFECTS OF WEATHER ON MILITARY OPERATIONS IN THE FORT BRAGG, NORTH CAROLINA, AREA

CONTENTS

NOTE: This document is based on past records. The information on certain weather conditions to be expected is based on the assumption that more or less average conditions will occur. Since extreme weather conditions occur only infrequently, the information presented herein is deemed accurate for planning purposes. For day-to-day forecasts of the actual time of occurrence of these conditions, and for information concerning departures from the normal during actual operations, consult the nearest Air Weather Service installation.

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MAJOR CLIMATIC CONSIDERATIONS

In general, this area has a maritime climate, due to the influence of the large high-pressure area practically always located over the ATLANTIC OCEAN, which pours moist air over this area from that moisture source and also from the GULF OF MEXICO. The air in the lower levels is fairly humid, and moderate to high temperatures prevail at this time of year (April, May, and June). Occasionally, continental air will invade this area from the west or northwest, causing slightly lower temperatures and humidities, but this type of air does not remain for very long periods of time in this season. Some fairly cold nights may exist during the early part of April, and occasionally the temperature gets very high in the June afternoons, but, in general, the weather does not cause physical discomfort.

The ATLANTIC OCEAN lies about 96 miles to the east. From the shore westward across NORTH CAROLINA, terrain rises slightly over most of the state, then rather abruptly in the APPALACHIAN MOUNTAINS which lie in the extreme western part of the state. The coastal plain lies in the eastern portion of the state and the area around FORT BRAGG is located on slightly higher ground to the west commonly referred to as the PIEDMONT PLATEAU. Mechanical lift of air up a slope can cause extensive cloudiness, but in this particular part of the state, terrain rises very slowly and topography has little effect on weather in the area. The higher terrain to the west, though, does have the effect of drying out air which moves in from that direction, resulting in less humid conditions in this area under those conditions. To the southwest and northeast, the coastal plain is fairly flat and terrain has practically no effect on the weather. The ATLANTIC OCEAN does have a slight effect. With northeast, east or southeast winds, the moist maritime air moving directly inland from the ocean is warmed from below, and forms a low cloud deck which is occasionally accompanied by light rain or drizzle.

GENERAL WEATHER INFORMATION
CLOUDINESS
APRIL

Average number of days with certain conditions of cloudiness at each hour

Hour (IST)	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Clear skies	15	15	13	13	14	11	9	9	9	10	9	8	7	6	6	6	5	6	7	8	12	14	14	15
Ceilings ** below 500 feet	1	*	*	1	1	1	1	1	1	1	*	*	*	0	*	*	*	*	*	*	*	*	*	*
Ceilings ** 500-1,000 feet	1	1	1	1	1	1	2	2	2	2	2	1	1	1	*	*	1	1	1	1	1	1	1	1
Ceilings ** 1,000-5,000 feet	3	4	4	5	5	5	4	5	4	5	5	7	8	8	9	9	7	5	6	5	4	4	4	4
Ceilings ** 5,000-10,000 feet	2	2	1	1	2	2	2	2	3	3	2	2	1	2	1	1	1	2	2	2	2	2	2	2
Overcast below 10,000 feet	5	5	6	7	7	7	7	7	7	7	5	5	5	5	5	5	5	4	4	5	5	5	6	6

* Occurs less than 5 days in 10 years. Six days to 15 days in 10 years considered as average of 1 day
** Base of lowest clouds covering half or more of sky

Average number of days with certain general cloudiness conditions at different times of day

	Morning	Afternoon	Night
Clear skies	10	6	15
Overcast skies (any altitude)	13	11	9
Low overcast skies (below 10,000 feet)	7	5	5
Low clouds below 1,000 feet which cover 5-tenths or more of the sky	3	1	2

It is interesting to note the rapidity with which clear conditions decrease between the hours of 0500 and 0700 LST, and increase between the hours of 2000 and 2200 LST. Clear conditions occur least frequently at 1700. Extremely low ceilings (below 500 feet) occur very infrequently, generally between the hours of 0400 and 1000 LST. These ceilings lift with daytime heating from the sun, which partially accounts for the most frequent occurrence of ceilings between 500 and 1,000 feet between the hours of 0700 and 1100 LST. As daytime heating increases, these clouds lift to between 1,000 and 5,000 feet; but, in addition, on many days even though no lower clouds are present in the early morning cloudiness of the "puffy" type begins to appear about 1000 LST and these two factors cause the maximum amount of cloudiness at this level to occur between the hours of 1100 and 1900 LST, when the sun sets; and clouds begin to dissipate with nightime cooling. During the early morning, clouds at very low levels are flat, usually in layers but during the afternoon, they are generally of the "puffy" type, although lower, flat clouds may form in precipitation areas. Low cloudiness is most often overcast in the morning hours. In the lower table, a distinction is made between overcast skies at any altitude, and overcast skies below 10,000 feet because, overcasts at very high altitudes may be very thin, while those at the lower levels are usually fairly thick and cut off practically all blue sky.

GENERAL WEATHER INFORMATION, PRECIPITATION -- April

Average precipitation (inches)	3.28
Maximum precipitation (inches)	9.21
Minimum precipitation (inches)	0.53
Maximum precipitation in a 24-hour period (inches)*	1.0-2.5
Average number of days with precipitation .01 inch or greater	7
Average number of days with thunderstorms	1

* between the limits given

Average distribution of days with precipitation:

Amount (inches)	None	Trace	(.01)	(.02-.05)	(.06-.10)	(.11-.25)
Number of days	19	4	**	1	1	2

Amount (inches)	(.26-.50)	(.51-1.0)	(1.0-2.5)
Number of days	1	1	1

** Occurs less than 5 times in 10 years

Snow did not occur in April during the last ten years. A trace of snow (less than .01 in.) was reported in a previous year. At first glance temperatures in April indicate that occasional snow might occur; however, these below-freezing temperatures normally occur only with clear skies at this time of year. All precipitation during this month is in form of rain or drizzle, and during the first part of the month, occurs as drizzle at any time of day, but in the latter part of the month occurs primarily as showers in the afternoon. Precipitation occurs a little more frequently about 1700 LST and a little less frequently at noon than at the other time of day, but these maxima and minima of occurrence are only slightly different from the occurrence at any other time of day. In ten years, freezing rain was reported once in April. Hail did not occur in the vicinity of FORT BRAGG in these ten years. On the average, a thunderstorm will occur on one day in April, and will probably occur between the hours of 1600 and 2000 LST. The occurrence of the maximum and minimum amounts of precipitation is very unusual and precipitation for the month will usually run between 2 and 5 in.

GENERAL WEATHER INFORMATION, TEMPERATURE -- April

Average temperature of month	61° F.
Highest temperature recorded in last 10 years	94° F.
Lowest daily maximum temperature recorded in last 10 years	44° F.
Average daily maximum temperature	74° F.

Operation Plan
TFAF No. 3-50

Lowest temperature recorded in last 10 years 24° F.

Highest daily minimum temperature recorded in last 10 years 66° F.

Average daily minimum temperature 48° F.

Average number of days with freezing temperature 2

Average number of days with temperatures above 90 F. 1

A general summary of the data for POPE AIR FORCE BASE, FORT BRAGG, which is given above, reveals the following information. Daily maximum temperatures will probably be between 94° F. and 44° F. the highest and lowest daily maximum temperatures on record. The majority of maximum temperatures will fall below 88° F. Daily minimum temperatures will probably be between 24° F. and 66° F., the lowest and highest daily minimum temperatures recorded. Daily minimum temperatures below freezing are quite rare. Since this month is in the transition period from winter to summer, temperatures will in general, become much warmer during the month; but the variation from day to day may be quite large. This information will be representative for the area surrounding FORT BRAGG; however, minimum temperatures in low spots may be a few degrees colder, especially in the early part of the month. Temperature at the surface is also dependent on such features of the topography as vegetation, type of soil, etc., but in general, in a zone of moderate temperatures and fairly flat terrain such as this, the temperatures throughout an area are fairly homogeneous.

GENERAL WEATHER INFORMATION VISIBILITIES -- April

Average number of hours with visibilities below certain limits

Limits	1/8 mi	1/4 mi	1/2 mi	3/4 mi	1 mi	2 1/4 mi	2 1/2 mi	6 mi
No. of hrs.	3	4	7	9	9	29	32	156

Average number of days on which visibilities occur below certain limits

Limits	1/8 mi	1/4 mi	1/2 mi	3/4 mi	1 mi	2 1/4 mi	2 1/2 mi	6 mi
No. of days	1	1	1	1	1	4	4	13

Visibilities in this area are generally good. Poorest visibility occurs about 0700 LST, the time of day used in computing the above table. Visibilities below 1 mile could be expected on 1 day in April, and may last for about 9 hours. Visibilities below 6 miles occur on about 13 days in the month, and on 4 or 5 of these days will persist throughout the day. Visibilities below 2½ miles will last all day on about 1 day during the month. The chief cause of low visibilities in this area is fog, which normally occurs shortly before, and lasts until shortly after, sunrise. Fog will occur in an intensity that limits visibility to 1 mile on only 1 day in April. It will occur in lesser intensity more frequently. Smoke and haze are occasional restrictions to visibility in the afternoon, and precipitation may somewhat restrict visibility at any time of day.

NOTE: Data used in this study were for POPE AIR FORCE BASE at FT BRAGG. Fog is a very special weather element in any area study, because its occurrence depends largely on the character of the terrain in question. It will form more frequently and more intensely in low areas, valleys, and over rivers than on fairly high, level ground. This should be considered when using the above data; however, the data presented should provide a good measuring device for frequency distribution in any case.

GENERAL WEATHER INFORMATION, SURFACE WINDS - APRIL

Data for POPE AIR FORCE BASE constitute the only available data on surface winds in this area. The data will not be too representative for the entire area as light surface winds are greatly affected by local terrain; even by such features as hills and ravines. Surface winds of higher speed, however, are more representative for the surrounding area, and thus some conclusions may be drawn as to surface winds in the area.

The prevailing surface wind in April is southwesterly, although southerly and westerly surface winds are common. Generally, easterly and southeasterly winds occur less frequently than those from the other directions. Calm conditions will occur in areas surrounding POPE AIR FORCE BASE with about the same frequency that they do at that point. The stronger winds can be expected from a south-southwesterly direction.

A more complete breakdown on surface winds at POPE AIR FORCE BASE, which is not presented here, indicated that the following information would also be representative for the area. Wind speeds of from 25 to 31 m.p.h. occur only infrequently, and are usually from a south or south-westerly direction. A wind speed of over 32 m.p.h. occurred only once in 10 years, and was from the southwest. The most frequently occurring wind is from the southwest, with a speed between 4 and 12 m.p.h. Very bad weather, with very low cloud bases or very low visibilities or both, occurs most frequently under calm conditions, but when wind is present, bad weather occurs most frequently with winds from the east or northeast having speeds between 4 and 12 m.p.h.

PERCENTAGE FREQUENCY OF SURFACE WIND BY DIRECTION
POPE AIR FORCE BASE
APRIL

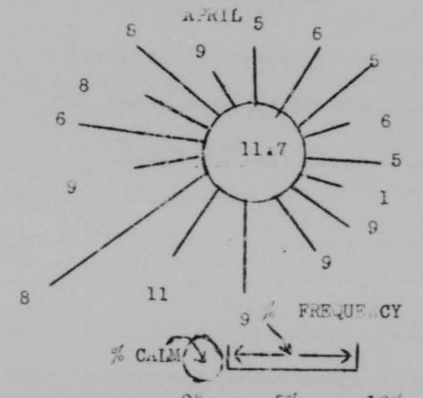

FIGURE AT END OF DIRECTION INDICATES MEAN SPEED IN MPH

GENERAL WEATHER INFORMATION, CLOUDINESS (May)

Average number of days with certain conditions of cloudiness at each hour

Hour (LST)	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Clear skies	15	15	14	14	11	6	7	8	9	9	7	6	5	4	4	4	4	4	5	5	8	11	12	14
Ceilings ** below 500 feet	*	1	1	1	1	2	2	*	*	*	*	*	*	0	0	*	*	*	0	0	*	*	*	*
Ceilings ** 500-1,000 feet	1	2	1	1	1	2	2	3	2	2	1	1	1	1	1	1	*	1	1	1	1	1	1	1
Ceilings ** 1000-5000 feet	4	3	3	3	4	4	4	4	5	7	7	10	11	12	11	10	9	6	6	5	4	3	2	3
Ceilings ** 5,000-10,000 feet	2	2	2	2	2	2	2	3	2	2	1	1	1	1	1	2	2	2	2	2	2	2	1	1
Overcast below 10,000 feet	5	5	5	6	7	6	6	6	6	4	4	3	4	3	3	3	3	4	4	4	4	5	4	4

* Occurs less than 5 days in 10 years. Six days to 15 days in 10 years considered as average of 1 day
** Base of lowest clouds covering half or more of sky

Average number of days with certain general cloudiness conditions at different times of day

	Morning	Afternoon	Night
Clear skies	9	4	14
Overcast skies (any altitude)	13	10	11
Low overcast skies (below 10,000 feet)	6	3	5
Low clouds below 1,000 feet which cover 5-tenths or more of the sky	4	1	2

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SECRET-SWARMER-SECRET

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The largest change in clear conditions occurs with a decrease between the hours of 0400 and 0600 LST and with an increase between the hours of 2000 and 2200 LST. Clear conditions occur least frequently between the hours of 1400 and 1700 LST. Extremely low ceilings (below 500 feet) occur very infrequently, generally between the hours of 0200 and 0700 LST. These ceilings lift with daytime heating from the sun, which partially accounts for the most frequent occurrence of ceilings between 500 and 1,000 feet between the hours of 0600 and 1000 LST. As daytime heating continues, these clouds lift to between 1,000 and 5,000 feet, but, in addition, on many days, even though no lower clouds are present in the early morning, cloudiness of the "puffy" type begins to appear about 1000 LST, and these two factors cause the greatest frequency of ceilings between 1,000 and 5,000 feet to occur between the hours of 1100 and 1700 LST, when cooling begins, and clouds become more broken. During the very early morning, extremely low clouds are flat, usually in layers, but shortly after sunrise become puffy, and most cloudiness in the daytime is of the "puffy" type. In areas of precipitation, lower clouds may be of the flat, layer type. Cloudiness above 5,000 feet is normally in layers, and may occur at any time of day. The sky is most often overcast with low cloudiness in the morning hours. In the lower table, a distinction is made between overcast skies at any altitude, and overcast skies below 10,000 feet because overcasts at very high altitudes may be very thin, while those at the lower levels are usually fairly thick and cut off practically all blue sky.

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TEAF No. 3-50

GENERAL WEATHER INFORMATION - PRECIPITATION (MAY)

Precipitation Chart for May

Average precipitation (inches)	4.19
Maximum precipitation (inches)	8.06
Minimum precipitation (inches)	0.66
Maximum precipitation in a 24-hour period (inches)*	1.0-2.5
Average number of days with precipitation .01 inch or greater	8
Average number of days with thunderstorms	1

* Between the limits given

Average distribution of days with precipitation

Amount (inches)	None	Trace	(.01)	(.02-.05)	(.06-.10)	(.11-.25)
Number of days	18	6	**	2	1	2

Amount (inches)	(.26-.50)	(.51-1.0)	(1.0-2.5)
Number of days	1	1	**

** Occurs less than 5 times in 10 years

All precipitation in the month of May occurs as rain or drizzle. Precipitation which occurs in the early morning hours is normally light rain or drizzle, but in the afternoon it is usually in the form of light or moderate showers. Precipitation occurs least frequently about noon and shortly after midnight, and most frequently about 0600 LST and 1700LST but there is no outstanding difference in the frequency of occurrence at any time of day. Thunderstorms occur on an average of 1 day in the month and will probably occur between the hours of 1600 and 1900 LST. The occurrence of the maximum and minimum amounts of precipitation is very unusual and odds are very much in favor of precipitation in the amounts of 3 to 5 inches

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IPAF No. 3-50

GENERAL WEATHER INFORMATION - TEMPERATURE (MAY)

Temperature Chart for May

Average temperature of month	60° F.
Highest temperature recorded in last ten years	99° F.
Lowest daily maximum temperature recorded in last ten years	52° F.
Average daily maximum temperature	82° F.
Lowest temperature recorded in last ten years	30° F.
Highest daily minimum temperature recorded in last ten years	73° F.
Average daily minimum temperature	57° F.
Average number of days with freezing temperatures	0
Average number of days with temperatures above 90° F.	5

A general summary of the data for POPE AIR FORCE BASE, FORT BRAGG, which is given above, reveals the following information. Daily maximum temperatures will probably be between 99° F. and 52° F., which are, respectively, the highest and lowest maximum daily temperatures recorded. The majority of maximum temperatures will fall below 94° F. Daily minimum temperatures will probably be between 30° F. and 73° F. as these are the lowest and highest minimum daily temperatures recorded. Daily minimum temperatures below 42° F. are rather infrequent. In general temperatures will be somewhat warmer toward the end of the month than they are at the beginning, but the effect will not be so noticeable as in April. This information will be representative for the area surrounding FORT BRAGG; however, minimum temperatures in low spots may occasionally be a few degrees colder, especially on the colder mornings. Temperature at the surface is also dependent on such features of the topography as vegetation, type of soil, etc., but, in general, in a zone of moderate temperatures and fairly flat terrain such as this, the temperatures throughout an area are fairly homogeneous.

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GENERAL WEATHER INFORMATION - VISIBILITIES (MAY)

Visibility Chart for May

Average number of hours with visibilities below certain limits

Limits	1/8 mi.	1/4 mi.	1/2 mi.	3/4 mi.	1 mi.
Number of hours	1	3	6	7	7
Limits	2-1/4 mi.	2-1/2 mi.	6 mi.		
Number of hours	21	23	107		

Average number of days on which visibilities occur below certain limits

Limits	1/8 mi.	1/4 mi.	1/2 mi.	3/4 mi.	1 mi.
Number of days	*	1	1	1	1
Limits	2-1/4 mi.	2-1/2 mi.	6 mi.		
Number of days	3	4	12		

* Occurs on less than 5 days in 10 years. Six days to 15 days in 10 years considered average 1 day

Visibilities in this area are generally good. Poorest visibility occurs about 0600 LST, the time of day used in computing the above table. Visibilities below 1 mile could be expected on 1 day in May and may last for approximately 7 hours. Visibilities below 2 1/2 miles can be expected on 4 days in May and will occur between the hours of 0300 and 1000 LST. Visibilities below 6 miles will occur on 12days, most frequently just before, and just after, sunrise, but will remain throughout the day about twice in the month. Fog is the chief cause of low visibilities in this area and occurs most frequently around sunrise. It will occur in an intensity that limits visibility to one mile on only 1 day in May. Smoke and/or haze is an occasional restriction to visibility around midday, and precipitation will occasionally restrict visibility, especially when it occurs in the afternoon in the form of moderately heavy showers.

NOTE: Data used in this study were for POPE AIR FORCE BASE AT FORT BRAGG. Fog is a very special weather element in any area study, because its occurrence depends largely on the character of the terrain in question. It will form more frequently and more intensely in low areas, valleys, and over rivers than on fairly high, level ground. This should be considered when using the above data; however, the data presented should provide a good measuring device for frequency distribution in any case.

• GENERAL WEATHER INFORMATION - SURFACE WINDS (MAY)

Data for POPE AIR FORCE BASE constitute the only available data on surface winds in this area. The data will not be too representative for the entire area as light surface winds are greatly affected by local terrain; even by such features as hills and ravines. Surface winds of higher speeds, however, are more representative for the surrounding area, and thus some conclusions may be drawn as to surface winds in the area.

The prevailing surface wind in May is southwesterly, although southerly winds are almost as common, and westerly winds also occur frequently. Calm conditions will occur in areas surrounding POPE AIR FORCE BASE with about the same frequency that they do at that point. Stronger surface winds occur most frequently from a southwesterly direction.

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A more complete breakdown on surface winds at POPE AIR FORCE BASE, which is not presented here, indicates that the following information would also be representative for the area. Wind speeds between 25 and 31 m.p.h. occur only rarely and are from a south or southwesterly direction when they do occur. The strongest wind reported in May was between 32 and 46 m.p.h., and came from the north-west. The most frequently occurring wind is from the south or south-west with a speed between 4 and 12 m.p.h. Very bad weather, with very low cloud bases or very low visibilities or both, occurs most frequently under calm conditions, but when wind is present bad weather occurs most frequently with winds from the southwest with speed between 4 and 12 m.p.h. and with winds from the northwest with speeds between 1 and 3 m.p.h.

PERCENTAGE FREQUENCY OF SURFACE WIND BY DIRECTION
POPE AIR FORCE BASE
MAY

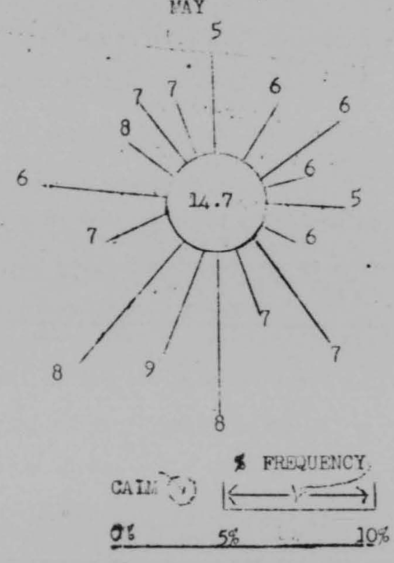

FIGURE AT END OF DIRECTION INDICATES MEAN SPEED IN MPH

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GROUND OPERATIONS

Chemical Warfare

Criteria: Surface wind speed 4-12 m.p.h. with temperatures 32°F. to 75°F. and no precipitation (percent of time).

	April	May	June
Maximum	54.6	43.1	27.1
Mean	44.3	33.7	17.8
Minimum	25.0	17.0	7.2

The above criteria approximate those which were set up for weather requirements by the SHEAF staff for D-Day in Japan. The percentages given represent the percentage occurrence of these favorable conditions with surface winds from any direction. The length of time allotted for the preparation of this report prohibited a breakdown into the percentage occurrence with surface winds from various directions, which would possibly have been more satisfactory. In general, the conditions set forth above as favorable for chemical warfare operations vary from a possible maximum of 54.6 percent of the time in May to a possible minimum of 7.2 percent of the time in June. One conclusion which may be drawn is that favorable conditions for chemical warfare decrease in frequency through the 3-month period.

Air Ground Support

Criteria: Ceilings equal to or greater than 950 feet and visibilities equal to or greater than 3 miles 9percent of time .

	April	May	June
Mean	92.7	93.1	94.4

Favorable conditions for air-ground support exist the greater part of the time in all three months, increasing slightly in frequency of occurrence from the beginning to the end of the 3-month period. In all three months, these conditions exist most frequently in the afternoon, when they occur on all but

0055

an average 1 day per month. They are least frequent in the hours between 0600 and 0900 LST, when unfavorable conditions exist on an average 4 or 5 days per month.

Camouflage: Very little can be stated about the effect of weather on this phase of military operations during April, May and June. Snow cover does not exist in the FORT BRAGG area during that period. Many of the trees in the area are of the evergreen type and those which are not begin to leaf out, if not before the first of April, shortly thereafter. Occasionally, during April, rain prohibits planting of crops, so that cultivated areas may be without foliage until late in the month or even into May.

STORAGE OF SUPPLIES AND EQUIPMENT.

Fairly humid air exists in this region in most of April, and practically all of May and June. Most of the air which moves into this region during these three months comes from off the ATLANTIC OCEAN or the GULF OF MEXICO, both of which are excellent sources of moisture. Occasionally in April drier air will move in from the west, but later in the season this occurrence becomes less frequent. Humidity will generally be highest in the morning and lowest in the evening. Freezing temperatures occur occasionally in early April, and occasional very hot temperatures occur in June, but normally temperatures during this period are moderate.

AERIAL OPERATIONS

Paratroop Operations

Criteria: Contact conditions, i.e., ceilings 950 ft. or over and visibilities 3 miles or over, with surface winds equal to or less than 21 m.p.h. (percent of time.)

	Apr	May	Jun
Maximum	96.3	96.1	98.5
Mean	92.0	92.1	94.0
Minimum	87.5	85.7	89.2

Using the above criteria to calculate percentage frequency of available weather for paratroop operation, we find that the maximum occurrence was 98.8 percent in June and the minimum 85.7 percent in May. The mean also shows June to be the most favorable month at 94.0 percent over May and April with 92.1 percent and 92.0 percent, respectively. The percentage difference is slight, however; there is only a 2.0 percent spread, so in conclusion any or all three months should produce enough satisfactory weather for paratroop operatiions.

GLIDER OPERATIONS

Criteria: Contact conditions with wind speeds less than 31 m.p.h. (percent of time)

	Apr	May	Jun
Maximum	96.7	96.1	98.8
Mean	92.3	92.2	94.0
Minimum	87.5	86.0	89.2

A criteria of 31 m.p.h. was used, as a maximum of 30-35 m.p.h. was set up for the original weather requirments by the SHEAF staff for the D-Day operations in JAPAN. Examining the Table, we find that all three months are very favorable for this operation. Percentages range from a maximum occurrence of 98.8 percent in June to a minimum of 86.0 percent in May. The spread in the means, however, shows a range of only 1.8 percent proving all months to be well within the range of satisfactory operational weather.

AERIAL PHOTOGRAPHIC OPERATIONS

Criteria: Cloud cover equal to or less than 2-tenths with visibilities equal to or greater than 6 miles (percent of time).

	Apr	May	Jun
Maximum	45.3	40.1	33.5
Mean	36.8	33.7	26.8
Minimum	25.8	25.1	22.9

This type of operation demands the best weather possible. The requirements are so high that a much smaller operational frequency results. As the table shows, the percentages are down in the 20-45 percent range with the maximum occurrence being 45.3 percent in April and the minimum 22.9 percent in June. The mean falls off from 36.5 percent in April to 33.7 percent in May and to 28.8 percent in June. This decrease in the mean is due to the increased surface heating of the earth as the sun comes more directly overhead. This leads to higher frequency of cloud cover over 2-tenths due to greater convective activity. Thus the best month for photographic operations is April, and weather becomes progressively worse through June.

MEDIUM AND FIGHTER BOMBER OPERATIONS

Criteria: Ceilings equal to or greater than 4,500 ft. with visibilities equal to or greater than 3 miles (percent of time).

	Apr	May	Jun
Maximum	89.2	90.6	85.0
Mean	78.2	77.7	75.7
Minimum	64.0	71.5	66.0

These criteria were also used to set up requirements for D-Day in JAPAN and in lieu of any other were used to typify conditions for this particular operation. The table shows a maximum occurrence of 90.6 percent in June and a minimum of 64.0 percent in April. The mean, however, shows a slight decrease from 78.2 percent in April to 75.7 percent in June. Thus, all three months are approximately within the same range of occurrence. The increase of the ceiling requirements to 4,500 feet explains why conditions are suitable for this type of operation only approximately three-fourths of the time.

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INCENDIARY BOMBING

Criteria: Surface winds equal to or greater than 13 m.p.h. with no precipitation (percent of time).

	Apr	May	Jun
Maximum	16.3	9.2	7.8
Mean	7.2	4.0	2.3
Minimum	0.1	0.0	0.0

As incendiary bombing is not pinpoint bombing, but rather an area bombing operation, the only criteria considered were the wind and precipitation. The occurrence of the required conditions ranges from a maximum of 16.3 percent in April to a minimum of zero (0.0 percent) in May and June. The mean shows April to be the best month for this operation with a 7.2 percent occurrence, ranging downward through May with 4.0 percent and June with 2.3 percent.

FLYING WEATHER

Criteria: Contact - ceilings equal to or greater than 950 feet and visibilities equal to or greater than 3 miles. Instrument -- ceiling 451 to 950 feet with visibilities equal to or greater than 1 mile and/or visibility greater than 1 mile but less than 3 miles with ceiling equal to or greater than 451 feet. Closed -- ceiling less than 451 feet and/or visibility less than 1 mile.

The following map and table show the frequency of contact, instrument, and closed flying weather at various bases within operational distance of FORT BRAGG, N.C. These bases are representative of the remaining bases in their respective areas. Except in the northeast area contact flying weather usually occurs more than 90 percent of the time. A great deal of low cloudiness occurs in the northeast during winter. April, May, and June are transition months between winter and summer flying periods. As the flying weather is comparatively good throughout the entire area during this period, correlations between the percent of concurring contact, instrument, and closed weather at FORT BRAGG and the various airfields were not thought necessary. However, it is entirely within the capabilities of this headquarters to provide this type of data if so required. With this type of data it is possible to set up the percentage frequency of different types of military operations between a friendly field of activity and an enemy and/or other friendly fields of activity.

1 Tab
Percentage Frequency of
Flying Weather

CHESTER L. SLUDER
Colonel, USAF

Authenticated:

W. E. Howard
W. E. HOWARD
Lt Col, USAF
Dir Intel

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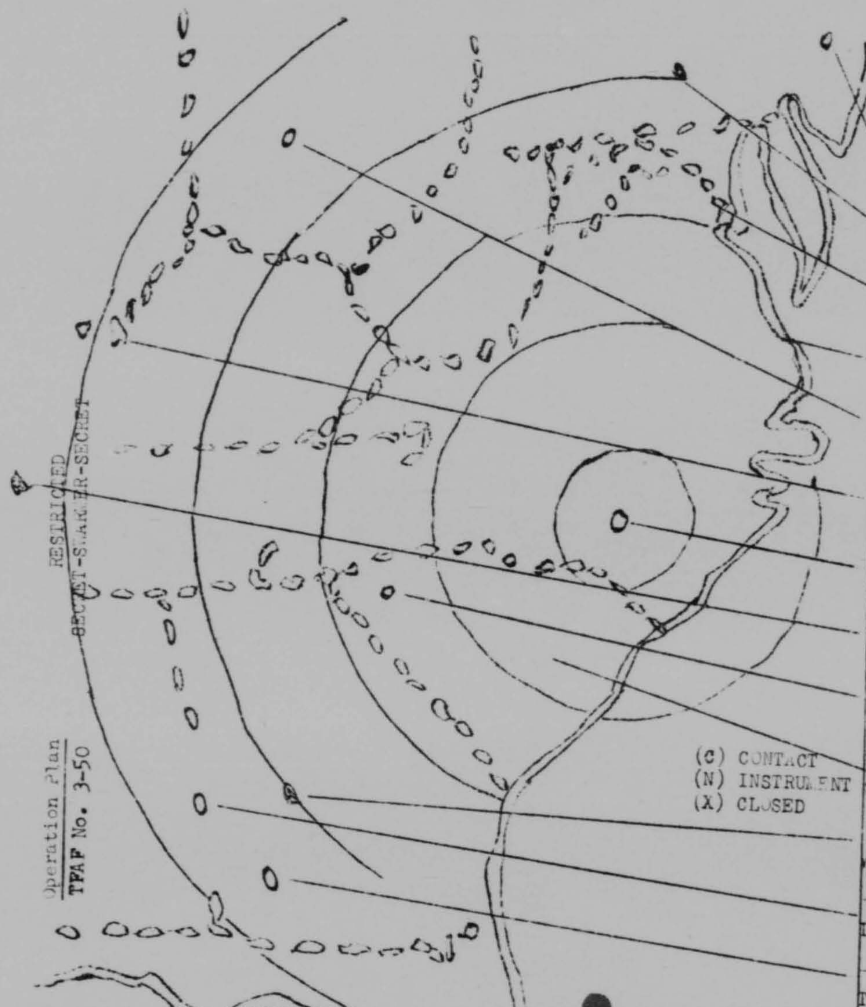

PERCENT FREQUENCY OF FLYING WEATHER AT VARIOUS AFB WITHIN A RADIUS OF 450 MILES OF FORT BRAGG, N.C. (C-N-X)

Station		Apr	May	Jun
MC GUIRE AFB, N.J.	C	82.7	83.7	86.5
	N	10.5	9.8	10.7
	X	6.8	6.5	2.8
OLMSTEAD AFB, PA	C	87.8	89.1	90.3
	N	9.6	9.2	8.3
	X	2.6	1.7	1.4
ANDREWS AFB, MD.	C	87.3	87.1	92.1
	N	6.5	8.3	5.1
	X	6.2	4.6	2.8
LANGLEY AFB, VA.	C	89.7	92.1	92.8
	N	6.7	5.7	5.8
	X	3.6	2.2	1.4
LOCKBOURNE AFB, OHIO	C	90.4	92.8	95.9
	N	8.7	6.2	3.5
	X	0.9	1.0	0.6
GODMAN AFB, NY.	C	86.0	94.0	94.0
	N	12.4	5.4	4.9
	X	1.6	0.6	1.1
POPE AFB, N.C.	C	92.7	93.1	94.4
	N	5.3	5.0	4.3
	X	2.0	1.9	1.3
SMYRNA AFB, TENN.	C	94.3	95.6	98,8
	N	4.4	3.9	1.1
	X	1.3	0.5	0.1
GREENVILLE AFB, S.C.	C	91.7	92.3	95.3
	N	5.1	5.1	3.3
	X	3.2	2.6	1.4
SHAW AFB, S.C.	C	91.5	93.9	96.1
	N	6.5	3.5	2.6
	X	2.0	2.6	1.3
WARNER ROBBINS AFB, GA.	C	92.7	95.7	96.5
	N	4.8	3.0	2.9
	X	2.5	1.3	0.6
LAWSON AFB, GA.	C	92.6	95.6	95.3
	N	5.4	3.5	3.7
	X	2.0	0.9	1.0
TURNER AFB, GA.	C	96.2	97.0	97.0
	N	3.0	2.3	2.2
	X	0.8	0.7	[illegible]

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TAB "A"

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Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
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APPENDIX VII TO ANNEX "C"

TACTICAL STUDY OF THE TERRAIN

1. FORT BRAGG.

a. The reservation at FORT BRAGG is generally pear-shaped with the stem pointed to the east, and its center located at 79°10'31" W 35°6'31" N. The east-west axis is approximately 24.2 miles, and the north-south axis is approximately 11.9 miles at the widest part.

(1) Drainage system. JAMES CREEK flows into LITTLE RIVER and forms the northern boundary of the reservation. A ridge line extends generally through the east-west axis forming a water shed and causing streams to flow to the north and south. Numerous wet weather streams and small creeks, with an occasional lake, are distributed at regular intervals on the north and south of the water shed.

(2) There is a main ridge line extending generally through the east-west axis with numerous projections to the north and south. There is a second prominent ridge in the south-western part of the reservation. The highest elevation is approximately 500 feet, and the lowest about 150 feet.

(3) Highways and roads. Three main third class roads extend from FORT BRAGG west through the reservation: MANCHESTER ROAD along the northern boundary; LONG STREET ROAD generally through the center; and, PLANK ROAD along the southern boundary. Several dirt roads extend north and south across the reservation forming an excellent network of dry weather roads.

(4) General nature of the terrain: The terrain is generally rolling and wooded with heaviest wooded area along the streams. The highest elevation is along the southwest boundary, and center of this area. The lowest elevation is at POPE FIELD

b. (1) Avenues of approach and lines of communication: Troops can approach FORT BRAGG from any direction, The best route of approach from the west would be along the east-west ridge line.

(2) Obstacles: There are no major obstacles in the area in dry weather. All streams except LITTLE RIVER are fordable. In wet weather motorized units would experience some difficulty in traversing this area due to dirt roads and numerous stream crossings.

(3) Concealment and cover: Cover seems to be generally good with areas along streams and creeks providing the best cover.

(4) Observation: Ground observation is good.

(5) Field of fire: Generally 360 degrees of fire exist for all weapons; ideal artillery positions are sometimes difficult to find.

c. Critical terrain features: The highest elevation is along the extreme southwest boundary. RAILROAD RIDGE, JOHNSON, BLUES, GADDYS, and CCOLYCONCH MOUNTAINS are considered critical points in this area.

d. Tactical effect of terrain: The terrain is this area is such as to facilitate military operations.

e. An overlay of simulated terrain features for problem purposes will be issued later.

f. See Tab A for information on airfield at POPE AFB.

2. CAMP MACKALL.

a. CAMP MACKALL is located 7 miles southwest of FORT BRAGG reservation and is separated by a corridor approximately 6 miles wide. The camp itself has no describable shape.

(1) Drainage systems: The area is drained by three main streams; DROWNING CREEK, SWAN CREEK, and ROCKY CREEK. Numerous other small creeks and wet weather streams are distributed throughout the area.

(2) There are two prominent hills and one ridge in the northwest portion of the area. Highest elevation is about 550 feet and the lowest about 250 feet.

(3) Highways and roads: U.S. HIGHWAY 1 and the SEABOARD AIR LINE RAILWAY runs through the center of the area from north to south. STATE HIGHWAY 15 and 501 extend through the western portion of the area on a north-south line. Numerous dirt roads and trails form an excellent network of dry weather roads over the entire area.

(4) General nature of the terrain: The terrain is generally rolling and wooded. Most of the area consisted of small farms prior to the time it became a reservation.

b. (1) Avenues of approach: Troops can approach from any direction. The rolling terrain is adaptable to any troop movements.

(2) Obstacles: There are no major obstacles of note.

(3) Concealment and cover: Cover is generally good. Concealment is thin and spotty in some locations.

(4) **Observation:** Ground observation is fair

(5) Fields of fire: Generally 360 degrees of fire exist for all weapons.

c. Critical terrain features: The critical terrain features are the **SANDHILLS AREA**. The remaining terrain is of such nature as to cause it to be neither critical nor vital.

d. Tactical effect of the terrain: The terrain in this area is such as to facilitate military operations.

e. An overlay of simulated terrain features for problem purposes will be issued later

f. See Tab B for information on airfield at **CAMP MACKALL**

CHESTER L. SLUDER
Colonel, USAF

2 Tabs
Tab "A" Diagram - POPE AFB
Tab "B" Diagram - MACKALL AIRBASE

Authenticated:
W. E. HOWARD
Lt. Col USAF
Dir Intel

0064

Operation Plan
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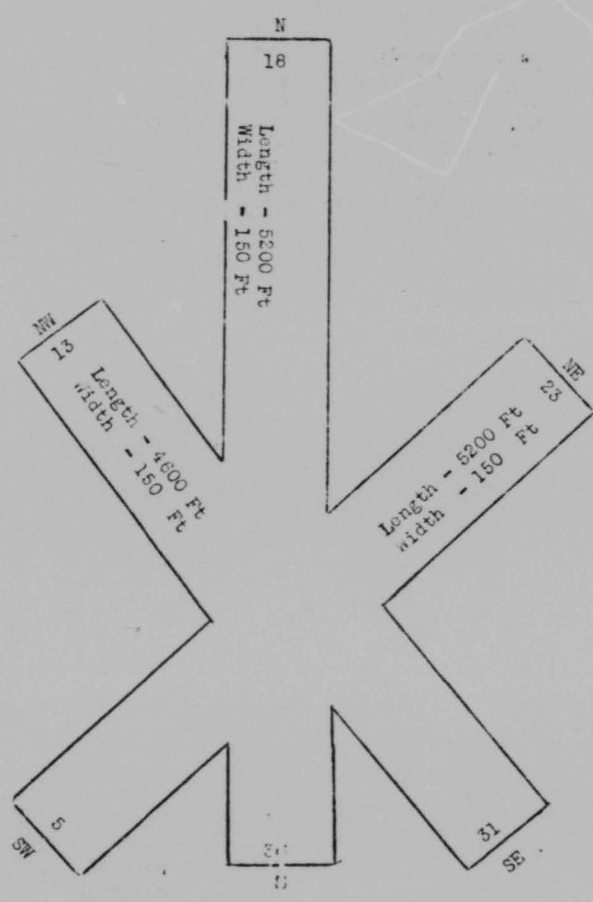
POPE AIR FORCE BASE

Elevation - 220 Feet above sea level
Call Letters - Fox Tare Baker
Runways - Concrete
Load Limit - 100,000 lbs per plane (Estimated)
Location - 1.2 miles Northwest of Fort Bragg

Largest planes known to have landed & taken off from runways are C-54 and Constellation



Tab "A"

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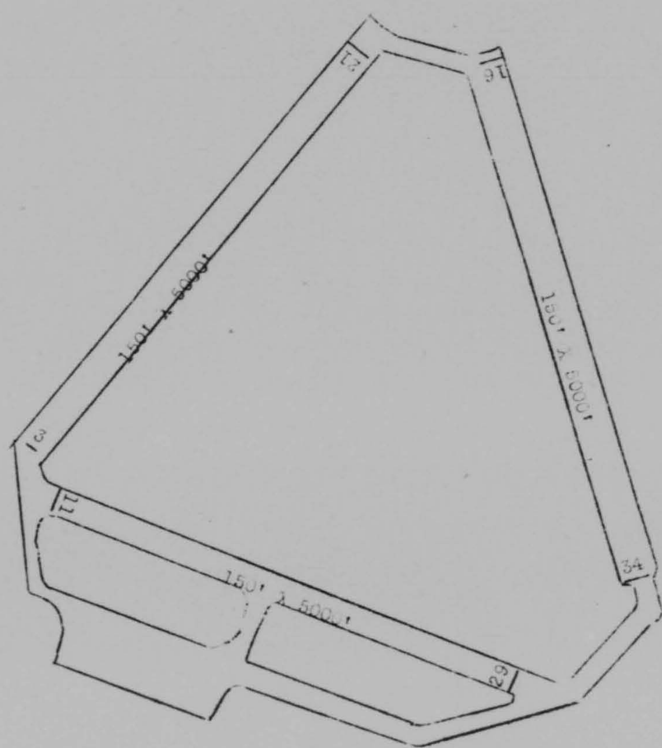
CAMP MACKALL AIRBASE

Elevation - 350 feet.
Runways - Concrete
Location - 28.5 miles
West Southwest of Pope AFB
Estimated load limits:
54,000 lbs continuous use
80,000 lbs occasional use
C-54 is largest a/c that has landed.
(Limited by length of runways).



Tab "B"

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SECRET-SWARMER-SECRET-

RESTRICTED

SECRET-SWARMER-SECRET

HEADQUARTERS
TASK FORCE AIR FORCE
EXERCISE SWARMER
POPE AIR FORCE BASE
FORT BRAGG, NORTH CAROLINA

OPERATION PLAN

TFAF 3-50

ANNEX D

AIR EMPLOYMENT

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TFAF No. 3-50

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

ANNEX D

AIR EMPLOYMENT

1. General:

a. Phases: Air operations during SWARMER are divided into phases as indicated:

(1) Phase 1 - Movement to maneuver area, 1 April 50 to 22 April 50.

(2) Phase 2 - Training, 1 April 50 to 20 April 50.

(3) Phase 3 - Air Reconnaissance, 15 April 50 to end of maneuver.

(4) Phase 4 - Air operations against Aggressor, 21 April 50 to end of maneuver.

(5) Phase 5 - Redeployment, 8 May 50 to 14 May 50.

2. Control:

a. Phase 1: Action to initiate movement of all units will be taken by SWARMER headquarters based upon schedules prepared by Task Force Air Force.

b. Phase 2:

(1) Upon arrival of units in the maneuver areas, control will be assumed by the Commanding General, Task Force Air Force, OUTER CAMP MACKALL. Units remaining at their home stations during the maneuver will come under the operational control of Task Force Air Force on 15 April 1950.

(2) Intensive unit training will be conducted upon arrival in the maneuver area until 21 April 1950 under the control of this headquarters. See Appendix II, this Annex.

c. Phase 3: Aerial Reconnaissance will be conducted against Aggressor from 15 April until the end of the maneuver. Reconnaissance missions will be as directed by JOC. See Annex D, Appendix I.

d. Phase 4: Combat air operations will be conducted against Aggressor during the period 21 April to 8 May 1950 as directed by the Commanding General, Task Force Air Force.

e. Phase 5:

(1) Movement orders will include instructions for return to home stations.

(2) Units will arrive at home stations not later than 2400 hours 14 May 1950.

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3. Operations:

a. Operations in the maneuver area will be in conformance with appendices attached to this annex.

Chester L. Sluder
CHESTER L. SLUDER
Colonel, USAF

Appendices:

I - Air Operations Schedule
II - Training
III - Air Defense
IV - Emergency Procedures
V - Safety and Control Procedures
VI - Objective Area Approach Procedures
VII - Map of the Objective Area

Operation Plan
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15 April thru 20 April

MSN No	MISSION	[illegible] No A/c and [illegible]	[illegible]	[illegible]	RENDEZVOUS	REMARKS
1.	RECCE	2 161st Recon Sq RF - 80's	0:45	As Directed	As Directed	Tactical Recon., Phase I, II, & III Targets
2.	RECCE	161st Recon Sq 2 RF - 80's	0:45	As Directed	As Directed	Tactical Recon., Phase I, II, & II. Targets
3.	RECCE	161st Recon Sq 2 RF - 80's	0:45	"	"	" "
4.	RECCE	161st Recon Sq 2 RF - 80's	0:45	"	"	" "
5.	RECCE	161st Recon Sq 2 RF - 80's	0:45	"	"	" "
6.	RECCE	161st Recon Sq 2 RF - 80's	0:45	"	"	" "

0070

Operation Plan
TFAF 3-50

AIR OPERATIONS SCHEDULE

D-Day Minus 4,5,6,7

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT TO CALL TO REPORT TO	RENDEZVOUS	REMARKS
1.	CAP	4th Ftr Gp 8 F-86's	0:30	As Directed	As Directed	During Daylight Hrs Condition I
2.	CAP	20th Ftr Gp 8 F-84's	1:30	As Directed	As Directed	During Daylight Hrs Condition I
3.	SWEEP	4th Ftr Gp 16- F-86's	0:30	As Directed	As Directed	Objective Area
4.	SWEEP	4th Ftr Gp 8 F-86's	0:30	As Directed	As Directed	Objective Area
5.	SWEEP	4th Ftr Gp 12 F-86's	0:30	As Directed	As Directed	Objective Area
6.	SWEEP	20th Ftr Gp 16 F-84's	0:10	As Directed	As Directed	Strafe-Dive Bomb
7.	SWEEP	20th Ftr Gp 12 F-84's	0:10	As Directed	As Directed	Strafe-Dive Bomb
8.	SWEEP	20th Ftr Gp 8 F-84's	0:10	As Directed	As Directed	Strafe-Dive Bomb
9.	SWEEP	20th Ftr Gp 8 F-84's	1:30	As Directed	As Directed	Objective Area
10.	STRIKE	84th 85th Bmr Sq 6 B-45's	0:10	As Directed	As Directed	High Level Bombing Enemy Airfield
11.	STRIKE	84th 85th Bmr Sq 6 B-45's	0:10	As Directed	As Directed	Low Level Bombing Enemy Airfield
12.	RECCE	161st Recon Sq 16 RF-80's	0:45	As Directed	As Directed	2A/C Flts Tactical Recon., Phases 1, 2 & 3 Target

D-1-2
RESTRICTED
SECRET - SWARMER - SECRET

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SECRET - SWARMER - SECRET

Operation Plan
TFAF - 3-50

AIR OPERATIONS SCHEDULE

D-Day Minus 3

MSN NO	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1.	CAP	4th Ftr Gp 16 F-86's	0900 to 1100	As Directed	As Directed	During Daylight Hrs 4 A/c Flts Each Thirty Minutes
2.	CAP	4th Ftr Gp 16 F-86's	1100 to 1300	"	"	" "
3.	CAP	4th Ftr Gp 16 F-86's	1700 to 1900	"	"	" "
4.	CAP	4th Ftr Gp 4 F-86's	0:30	"	"	During Daylight Hrs Condition I
5.	CAP	20th Ftr Gp 4 F-84's	1:30	"	"	" "
6.	SWEEP	4th Ftr Gp 12 F-86's	0:30	"	"	Objective Area
7.	SWEEP	4th Ftr Gp 8 F-86's	0:30	"	"	" "
8.	SWEEP	20th Ftr Gp 8 F-84's	0:10	"	"	Strafe-Dive Bomb Enemy Airfield (Langley)
9.	SWEEP	20th Ftr Gp 8 F-84's	0:10	"	"	Strafe-Dive Bomb Enemy Airfield
10.	SWEEP	20th Ftr Gp 8 F-84's	1:30	"	"	Objective Area
11.	SWEEP	20th Ftr Gp 8 F-84's	1:30	"	"	" "
12.	STRIKE	20th Ftr Gp 16 F-84's	0:10	"	"	Rocket & Strafe Enemy Airfield
13.	STRIKE	20th Ftr Gp 16 F-84's	0:10	"	"	Dive-Bomb & Strafe Enemy Positions
14	STRIKE	20th Ftr Gp 8 F-84's	0:10	"	"	Skip Bomb & Strafe Enemy Positions
15.	STRIKE	84th 85th Bmr Sq 6 B-45's	0:10	"	"	High Alt. Bombing Enemy Airfield
16.	STRIKE	84th 85th Bmr Sq 6 B-45's	0:10	"	"	Low Level Bombing Enemy Airfield

D-I-3
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Operation Plan
TF 3--50

AIR OPERATIONS SCHEDULE

D Day Minus 3

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
17.	STRIKE	84th 85th Bmr Sq 12 B-45's	0:10	As Directed	As Directed	Obj. Area High Level Bombing Enemy Installations
18.	RECCE	161st Recon Sq 16 RF-80's	0:45	"	"	2 A/c Flts Tactical Recon., Phase 1,2, & 3 Targets

Operation Plan
TF.F- 3-50

AIR OPERATIONS SCHEDULE

D-Day Minus 2

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1.	CAP	4th Ftr Gp 16 F-86's	0600 to 0800	As Directed	As Directed	4 c Flts Each Thirty Minutes
2.	CAP	4th Ftr Gp 16 F-86's	1100 to 1300	"	"	" " "
3.	CAP	4th Ftr Gp 16 F-86's	1700 to 1900	"	"	" " "
4.	CAP	4th Ftr Gp 4 F-86's	0:30	"	"	During Daylight Hrs Condition I
5.	CAP	20th Ftr G 4 F-84's	1:30	"	"	" " "
6.	SWEEP	4th Ftr Gp 12 F-86's	0:30	"	"	Objective Area
7.	SWEEP	4th Ftr Gp 8 F-86's	0:30	"	"	" "
8.	SWEEP	20th Ftr Gp 16 F-84's	0:10	"	"	Strafe & Rocket Enemy Airfield
9.	SWEEP	20th Ftr Gp 12 F-84's	0:10	"	"	" " "
10.	SWEEP	20th Ftr Gp 16 F-84's	1:30	"	"	Objective Area
11.	STRIKE	20th Ftr Gp 12 F-84's	0:15	"	"	Dive-Bomb & Strafe Enemy Position Obj. Area
12.	STRIKE	20th Ftr Gp 12 F-84's	0:15	"	"	" " "
13.	STRIKE	84th 85th Bmr Sq 12 B-45's	0:10	"	"	High Alt. Bombing Enemy Installations
14.	STRIKE	84th 85th Bmr Sq 6 B-45's	0:10	"	"	Low Level Bombing Enemy Airfield
15.	STRIKE	84th 85th Bmr Sq 6 B-45's	0:10	"	"	High Alt Bombing Enemy Airfield
16.	RECCO	1[illegible]1st Recon Sq 10 RF-80's	0:45	"	"	5-2 A/c Flts Tactical Recon., Phase 1,2, & 3 Targets

Operation Plan
TFAF 2-50

AIR OPERATIONS SCHEDULE

D Day Minus 1

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1.	CAP	4th Ftr Gp 4 F-86's	0:30	As Directed	As Directed	During Daylight Hrs Conditions 1
2.	CAP	4th Ftr Gp 16 F-86's	0600 to 0800	"	"	4 A/c Flts Each Thirty Minutes
3.	CAP	4th Ftr Gp 16 F-86's	1100 to 1300	"	"	" " "
4.	CAP	4th Ftr Gp 16 F-86's	1700 to 1900	"	"	" " "
5.	CAP	20th Ftr Gp 4 F-84's	1:30	"	"	" " "
6.	SWEEP	20th Ftr Gp 8 F-84's	0:10	"	"	Strafe Enemy Airfield
7.	SWEEP	4th Ftr Gp 8 F-86's	0:30	"	"	Objective Area
8.	SWEEP	4th Ftr Gp 8 F-86's	0:30	"	"	" "
9.	SWEEP	20th Ftr Gp 12 F-84's	0:10	"	"	Strafe Enemy Airfields
10.	SWEEP	4th Ftr Gp 8 F-86's	0:30	"	"	Objective Area
11.	SWEEP	20th Ftr Gp 8 F-84's	0:10	"	"	Strafe Enemy Airfields
12.	STRIKE	84th 85th Bmr Sq 6 B-45's	0:10	"	"	High Level Bombing Enemy Airfields
13.	STRIKE	84th 85th Bmr Sq 6 B-45's	0:10	"	"	High Level Bombing Objective Area
14.	STRIKE	84th 4th Bmr Sq 6 B-45's	0:10	"	"	Low Level Bombing Enemy Airfields
15.	STRIKE	20th Ftr Gp 12 F-84's	0:10	"	"	Rocket & Strafe Enemy Installation on Enemy Airfields
16.	STRIKE	20th Ftr Gp 8 F-84's	0:15	"	"	Dive-Bomb & Strafe Enemy Position In Objective Area

D-I-6
RESTRICTED
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Operation Plan
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AIR OPERATIONS SCHEDULE

D Day Minus 1

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
17.	STRIKE	20th Ftr Gp 12 F-84's	0:10	As Directed	As Directed	Skip Bomb & Strafe Enemy Installations on Airfields
18.	STRIKE	20th Ftr Gp 8 F-84's	0:15	"	"	Strafe Enemy Position Objective Area
19.	RECCE	161st Recon Sq 16 RF-80's	0:45	"	"	8--2 A/c Flts Tactical Recon., Phase 1, 2, 3, Targets

D-I-7
RESTRICTED

SECRET - SECURITY - SECRET

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Operation Plan
TFAF - 3-50

AIR OPERATION SCHEDULE

D-Day

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1	CAP	20th Ftr Gp 4- F-84D's	1:00	As Directed	As Directed	Shaw AFB - Congaree AB - GCI Controlled
2	CAP	20th Ftr Gp 4- F-84D's	1:00	As Directed	As Directed	Shaw AFB - Congaree AB - GCI Controlled
3	CAP	20th Ftr Gp 4- F-84D's	1:00	As Directed	As Directed	Shaw AFB - Congaree AB - GCI Controlled
4	CAP	20th Ftr Gp 4- F-84D's	1:00	As Directed	As Directed	Shaw AFB - Congaree AB - Condition I Daylight Hours
5	CAP	4th Ftr Gp 4- F-86's	:30	As Directed	As Directed	Maxton - Mackall AB - GCI Controlled
6	CAP	4th Ftr Gp 4- F-86's	:30	As Directed	As Directed	Maxton - Mackall AB - GCI Controlled
7	CAP	4th Ftr Gp 4- F-86's	:30	As Directed	As Directed	Maxton - Mackall AB - GCI Controlled
8	CAP	4th Ftr Gp 4- F-86's	:30	As Directed	As Directed	Maxton - Mackall AB - GCI Controlled
9	CAP	4th Ftr Gp 4- F-86's	:30	As Directed	As Directed	Maxton - Mackall AB - GCI Controlled
10	CAP	4th Ftr Gp 4- F-86's	:30	As Directed	As Directed	Condition I During Daylight Hours
11	ESCORT	20th Ftr Gp 12 F-84's	:25	"	"	1st Troop Drop in Objective Area
12	ESCORT	20th Ftr Gp 12 F-84's	:25	"	"	2nd Troop Drop in Objective Area
13	ESCORT	20th Ftrs Gp 12 F-84's	:25	"	"	3rd Troop Drop in Objective Area
14	ESCORT	4th Ftr Gp 8 F-86's	:10	"	"	B-45's Msn. 15
15	STRIKE	84th 85th Bmr Sq 6 B-45's	:10	"	"	High Level Bombing Objective Area
16	STRIKE	20th Ftr Gp 8 F-84's	:10	"	"	Rocket & Strafe Enemy Airfields

D-I-8
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Operation Plan
TFAF -3-50

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D-Day

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
17.	STRIKE	34th 85th Bmr Sq 12 B-45's	:10	As Directed	As Directed	Low Level Bomb Enemy Airfield
18.	STRIKE	34th 85th Bmr Sq 12 B-45's	:10	"	"	Frag Bomb Objective Area
19.	STRIKE	20th Ftr Gp 12 F-84's	:10	"	"	Rocket & Strafe Enemy Airfields
20.	STRIKE	4th Ftr Gp 4 F-86's	:10	"	"	Strafe Objective Area
21.	SUPPORT	20th Ftr Gp 8 F-84's	:15	"	"	For Ground Support
22.	SUPPORT	20th Ftr Gp 8 F-84's	:15	"	"	" "
23.	SWEEP	4th Ftr Gp 4 F-86's	:30	"	"	1st Troop Area Msn 11
24.	SWEEP	4th Ftr Gp 4 F-86's	:30	"	"	2nd Troop Area Msn 12
25.	SWEEP	4th Ftr Gp 4 F-86's	:30	"	"	3rd Troop Area Msn 13
26.	SWEEP	4th Ftr Gp 4 F-86's	:30	"	"	Troop Drop Area After Troop Aircraft have Departed
27.	SWEEP	20th Ftr Gp 4 F-84's	:40	"	"	Lane(3) and Objective Area after Troop Drop
28.	SWEEP	4th Ftr Gp 8 F-86's	:30	"	"	Objective Area
29.	SWEEP	4th Ftr Gp 8 F-86's	:30	"	"	" " "
30.	SWEEP	4th Ftr Gp 4 F-86's	:30	"	"	" " "
31.	SWEEP	4th Ftr Gp 4 F-86's	:30	"	"	" " "
32.	SUPPORT	20th Ftr Gp 8 F-84's	:15	"	"	For Ground Support

D-I-9
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Operation Plan
FAF – 3-50

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D-Day

S. No	MISSION	[illegible]	[illegible]	UNIT AND [illegible] REPORT TO	RENDEZVOUS	REMARKS
33.	SUPPORT	20th Ftr Gp 8 F-84's	:15	As Directed	As Directed	For Ground Support
34.	SUPPORT	4th Ftr Gp 8 F-86's	:15	"	"	" " "
35.	SWEEP	4th Ftr Gp 8 F-86's	:30	"	"	Objective Area
36.	SWEEP	4th Ftr Gp 8 F-86's	:30	"	"	" "
37.	RECON	161st Recon Sq 24 RF-80's	:45	"	"	12-(2) A/c Flts Tactical Recon Phase 1, 2, 3

D-I-10
RESTRICTED
SECRET - SWARMER - SECRET

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Operation Plan
TRAY 3-50

AIR OPERATION SCHEDULE D Day Plus 1

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1	CAP	20th Ftr Gp 4 - F-84D's	1:30	As Directed	As Directed	Shaw AFB - Congaree AB - GCI Controlled
2	CAP	20th Ftr Gp 4-F-84D's	1:30	As Directed	As Directed	Shaw AFB - Congaree AB - Condition I Daylight Hours
3	CAP	4th Ftr Gp 4- F-86's	:30	"	"	Maxton - Mackall AB - Condition I Daylight Hours
4	CAP	4th Ftr Gp 4- F-86's	:30	"	"	Maxton - Mackall AB - GCI Controlled
5	CAP	4th Ftr Gp 4- F-86's	:30	"	"	" "
6	CAP	4th Ftr Gp 4- F-86's	:30	"	"	" "
7	CAP	4th Ftr Gp 4-F-86's	:30	"	"	" "
8	ESCORT	20th Ftr Gp 12 - F-84D's	As Reqd	"	"	1st Resupply in Drop Area
9	ESCORT	20th Ftr Gp 12- F-84D's	As Req	"	"	2nd Resupply in Drop Area
10	ESCORT	4th Ftr Gp 8 - F-86's	:10	"	"	B-45 Mission #12 High Cover
11	ESCORT	4th Ftr Gp 8 - F-86's	:10	"	"	B-45 Mission #13 High Cover
12	STRIKE	84th 85th Bmr Sq 6 - B-45's	:10	"	"	Frag Bomb Objective Area
13	STRIKE	84th 85th Bmr Sq 6- B-45's	:10	"	"	High Level Bombing of Enemy Air Fields
14	STRIKE	84th 85th Bmr Sq 6 - B-45's	:10	"	"	Low Level Bombing of Objective Area
15	STRIKE	20th Ftr Gp 8 - F-84D's	:15	"	"	Dive Bombing of Objective Area
16	STRIKE	20th Ftr Gp 16 - F-84D's	:10	"	"	Strafing and Rocket Attack on Enemy Air Fields

D-I-11
RESTRICTED
SECRET - SWARMER - SECRET

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Operation Plan
TF.F 3-50

AIR OPERATIONS SCHEDULE

D Day Plus 1

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
17	STRIKE	20th Ftr Gp 4-F84D's	:15	As Directed	As Directed	Napalm Bombing of Objective Area
18	STRIKE	20th Ftr Gp 8-F84D's	:15	"	"	Dive Bombing of Objective Area
19	STRIKE	20th Ftr Gp 8-F84D's	:15	"	"	Strafing & Rocket Attack on Objective Area
20	SWEEP	4th Ftr Gp 4-F86's	:30	"	"	Objective Area
21	SWEEP	4th Ftr Gp 4-F86's	:30	"	"	Objective Area-Enemy Aircraft
22	SWEEP	4th Ftr Gp 8-F86's	:30	"	"	" "
23	SWEEP	20th Ftr Gp 8-F84D's	:10	"	"	Shaw AFB-Langley AFB Lane A-B
24	SWEEP	4th Ftr Gp 8-F86's	:30	"	"	Objective Area - Lane A
25	SWEEP	4th Ftr Gp 4-F86's	:30	"	"	Objective Area - Lane B
26	SWEEP	4th Ftr Gp 4-F86's	:30	"	"	Objective Area - Entrance Lanes
27	SWEEP	4th Ftr Gp 8-F86's	:30	"	"	Objective Area - As Directed
28	SUPPORT	4th Ftr Gp 8-F86's	:10	"	"	For Strafing
29	SUPPORT	4th Ftr Gp 8-F86's	:10	"	"	" "
30	SUPPORT	20th Ftr Gp 8-F84D's	:15	"	"	For Dive Bombing
31	SUPPORT	20th Ftr Gp 8-F84D's	:15	"	"	Strafe - Rocket
32	RECCE	161st Recon 18-RF-80's	:45	"	"	Tactical Recon. 9 Flights (2 Acft per Flight)

D-I-1k
RESTRICTED
SECRET - SECRET - SECRET

RESTRICTED
SECRET - SECRET - SECRET

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D-I-13
RESTRICTED

Operation Plan
TEAT 3-50

AIR OPERATION SCHEDULE

D Day Plus 2

MSN NO	MISSION	GRP IDENT No A/C and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1	CAP	20th Ftr Gp 4-F84D'S	0630 to 0800	As Directed	As Directed	Shaw - Congree - G.C.I. Controlled
2	CAP	20th Ftr Gp 4-F84D'S	1:30	" "	" "	Condition I - Daylight Hrs
3	CAP	4th Ftr Gp 4-F86'S	0630 to 0700	" "	" "	Maxton-Mackall - G.C.I. Controlled
4	CAP	4th Ftr Gp 4 F-86's	1200 to 1230	" "	" "	Maxton-Mackall - G.C.I. Control
5.	CAP	4th Ftr Gp 4 F-86's	:30	" "	" "	Daylight Hrs Conditions 1
6.	ESCORT	20th Ftr Gp 8 F-84's	1:30	" "	" "	Resupply Transports
7.	ESCORT	20th Ftr Gp 8 F-84's	1:30	" "	" "	" "
8.	ESCORT	20th Ftr Gp 8 F-84's	1:30	" "	" "	" "
9.	AREACOVER	4th Ftr Gp 8 F-86's	:30	" "	" "	Resupply Transports
10.	STRIKE	84th 85th Bmr Sq 6 B-45's	:10	" "	" "	High Level Bombing Enemy Airfield
11.	STRIKE	84th 85th Bmr Sq 6 B-45's	:10	" "	" "	Objectuve Area Low Level Bombing
12.	STRIKE	84th 85th Bmr Sq 3 B-45's	:10	" "	" "	Objective Area Frag Bombing
13.	STRIKE	20th Ftr Gp 8 F-84's	:15	" "	" "	Dive-Bomb Objective Area
14.	STRIKE	20th Ftr Gp 8 F-84's	:10	" "	" "	Napalm Bomb Objective Area
15.	STRIKE	4th Ftr Gp 8 F-86's	:10	" "	" "	Strafe Objective Area
16.	STRIKE	20th Ftr Gp 4 F-84's	:10	" "	" "	Dive Bomb & Strafe Enemy Airfield

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Operation Plan
TFAF 3-50

AIR OPERATIONS SCHEDULE

D Day Plus 2

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
17.	STRIKE	4th Ftr Gp 4 F-86's	:10	As Directed	As Directed	Strafe Objective Area
18.	SWEEP	4th Ftr Gp 8 F-86's	:30	"	"	Objective Area
19.	SWEEP	4th Ftr Gp 8 F-86's	:30	"	"	" "
20.	SWEEP	4th Ftr Gp 4 F-86's	:30	"	"	" "
21.	SWEEP	20th Ftr Gp 8 F-84's	:10	"	"	Strafe Enemy Airfields
22.	SWEEP	4th Ftr Gp 8 F-86's	:30	"	"	Objective Area
23.	SUPPORT	4th Ftr Gp 12 F-86's	:10	"	"	Strafe
24.	SUPPORT	20th Ftr Gp 16 F-84's	:15	"	"	Napalm Bomb
25.	SUPPORT	34th 85th Bmr Sq 6 B-45's	:10	"	"	Frag Bomb
26.	SUPPORT	4th Ftr Gp 4 F-86's	:10	"	"	Strafe
27.	SUPPORT	20th Ftr Sq 16 F-84's	:15	"	"	Dive Bomb
28.	SUPPORT	4th Ftr Gp 8 F-86's	:10	"	"	Strafe
29.	SUPPORT	20th Ftr Gp 4 F-84's	:15	"	"	Rocket Bombing
30.	RECCE	161st Recon Sq 16 RF-80's	1:00	"	"	Tactical Recon 8 (2) A/c Flts Phase 1, 2, &3 Targets

D-I-14
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Operation Plan
TFAF - 3-50

AIR [illegible] SCHEDULE

D-Day Plus 3

MSN No	MISSION	ORGANIZATION No A/C and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1.	CAP	20th Ftr Gp 4 F-84's	0630 to 0900	As Directed	As Directed	Shaw-Congaree G.C.I. Controlled
2.	CAP	20th Ftr Gp 4 F-84's	1:30	"	"	Daylight Hrs Condition I
3.	CAP	4th Ftr Gp 4 F-86's	0630 to 0900	"	"	Maxton-Mackall G.C.I. Controlled
4.	CAP	4th Ftr Gp 4 F-86's	:30	"	"	Daylight Hrs Conditions I
5.	ESCORT	20th Ftr Gp 8 F-84's	1:30	"	"	Resupply Transports
6.	ESCORT	20th Ftr Gp 8 F-84's	1:30	"	"	" "
7.	AREA COVER	4th Ftr Gp 8 F-86's	:30	"	"	" "
8.	STRIKE	84th 85th Bmr Sq 6 B-45's	:15	"	"	High Level Bombing Enemy Airfield
9.	STRIKE	84th 85th Bmr Sq 6 B-45's	:15	"	"	Objective Area Frag Bomb
10.	STRIKE	84th 85th Bmr Sq 3 B-45's	:15	"	"	Low Level Bombing Objective Area
11.	STRIKE	84th 85th Bmr Sq 3 B-45's	:15	"	"	High Level Bombing Objective Area
12.	STRIKE	20th Ftr Gp 16 F-84's	:10	"	"	Dive Bombing & Strafing Enemy Airfields
13.	STRIKE	4th Ftr Gp 12 F-86's	:10	"	"	Strafe Objective Area
14.	SWEEP	4th Ftr Gp 4 F-86's	:30	"	"	Objective Area
15.	SWEEP	4th Ftr Gp 8 F-86's	:20	"	"	" "
16.	SWEEP	4th Ftr Gp 8 F-86's	:30	"	"	" "

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Operation Plan
TFAF - 3-50

AIR OPERATIONS SCHEDULE

D-Day Plus 3

MSN No	MISSION	ORGANIZATION No A/c and TYP	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
17.	SWEEP	20th Ftr Gp 8 F-84's	:10	As Directed	As Directed	Enemy Airfields
18.	SWEEP	4th Ftr Gp 4 F86's	:30	"	"	Objective Area
19.	SWEEP	4th Ftr Gp 4 F-86's	:30	"	"	" "
20.	SUPPORT	20th Ftr Gp 8 F-84's	:15	"	"	Napalm Bomb
21.	SUPPORT	20th Ftr Gp 8 F-84's	:15	"	"	" "
22.	SUPPORT	20th Ftr Gp 8 F-84's	:15	"	"	Dive Bomb
23.	SUPPORT	4th Ftr Gp 4 F-86's	:10	"	"	Strafe
24.	SUPPORT	4th Ftr Gp 3 F-86's	:10	"	"	Strafing
25.	SUPPORT	4th Ftr Gp 8 F-86's	:10	"	"	"
26.	SUPPORT	4th Ftr Gp 4 F-86's	:10	"	"	"
27.	RECCE	161st Recon Sq 16 RF-80's	:45	"	"	Tactical Recon Msn 20 8 (2) A/c Flts Phase 1,2,3 Targets

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Operation Plan
TF 3-50

AIR OPERATION SCHEDULE

D-Day Plus 4

Msn No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1	CAP	20th Ftr Gp 4 - F-84D's	1:30	As Directed	As Directed	Condition I Daylight Hours
2	CAP	4th Ftr Gp 4 - F-86's	:30	"	"	" "
3	ESCORT	20th Ftr Gp 8 - F-84D's	1:30	"	"	Resupply Transport
4	ESCORT	20th Ftr Gp 8 - F-84D's	1:30	"	"	" "
5	STRIKE	84th 85th Bmr Sq 12 - B-54's	:15	"	"	High Level Bombing of Enemy Air Fields
6	STRIKE	20th Ftr Gp 12 - F-84D's	:10	"	"	Rocket - Strafe Enemy Fields
7	STRIKE	20th Ftr Gp 12 - F-84D's	:10	"	"	Dive Bomb Enemy Air Fields
8	STRIKE	84th 85th Bmr Sq 6 - B-45's	:10	"	"	Low Level Bombing of Objective Area
9	STRIKE	4th Ftr Gp 12 - F-86's	:10	"	"	Strafe Objective Area
10	SWEEP	4th Ftr Gp 8 - F-86's	:30	"	"	Objective Area
11	SWEEP	4th Ftr Gp 8 - F-86's	:30	"	"	Objective Area
12	SWEEP	4th Ftr Gp 4 - F-86's	:30	"	"	" "
13	SWEEP	4th Ftr Gp 8 - F-86's	:30	"	"	" "
14	SWEEP	4th Ftr Gp 8 - F-86's	:30	"	"	" "
15	SUPPORT	20th Ftr Gp 16 - F-84D's	:15	"	"	Rockets - Strafe
16	SUPPORT	20th Ftr Gp 16 - F-84D's	:15	"	"	Strafe - Bomb

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Operation Plan
TFAF 3-50

AIR OPERATIONS SCHEDULE

D-Day Plus 4

MSN No	MISSION	ORGANIZATION No A/c and Type	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
17	SUPPORT	20th Ftr Gp 12 - F-84D's	:15	As Directed	As Directed	Dive Bomb
18	SUPPORT	4th Ftr Gp 8 - F-86's	:10	"	"	Strafe as Required
19	SUPPORT	4th Ftr Gp 8 - F-86's	:10	"	"	" "
20	SUPPORT	4th Ftr Gp 8 - F-86's	:10	"	"	" "
21	RECCE	161st Recon 16 RF-80's	:45	"	"	Phase 1, 2, and 3 Tactical Recon. 8 Flights (2 Aircraft Each Flight)

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Operation Plan
TWAF 3-50

AIR OPERATIONS SCHOOL   D Day Plus 5

M.S.N No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1	CAP	20th Ftr Gp 4 - F-84D's	1:30	As Directed	As Directed	Condition I Daylight Hours
2	CAP	4th Ftr Gp 4 - F-86's	:30	"	"	" "
3	ESCORT	20th Ftr Gp 12 - F-84D's	1:30	"	"	Resupply Transport
4	ESCORT	20th Ftr Gp 12 - F-84D's	1:30	"	"	" "
5	STRIKE	84th 85th Bmr Sq 6 - B-45's	:10	"	"	High Level Bombing of Enemy Air Fields
6	STRIKE	84th 85th Bmr Sq 6 - B-45's	:10	"	"	High Level Bombing of Objective Area
7	STRIKE	20th Ftr Gp 12 - F-84D's	:15	"	"	Dive Bomb - Strafe Enemy Air Fields
8	STRIKE	4th Ftr Gp 12 - F-86's	:10	"	"	Strafe Objective Area
9	SWEEP	4th Ftr Gp 16 - F-86's	:30	"	"	Objective Area
10	SWEEP	4th Ftr Gp 12 - F-86's	:30	"	"	" "
11	SWEEP	4th Ftr Gp 12 - F-86's	:30	"	"	" "
12	SWEEP	20th Ftr Gp 12 - F-84D's	1:30	"	"	" "
13	SUPPORT	84th 85th Bmr Sq 6 - B-45's	:10	"	"	Low Level Bomb
14	SUPPORT	20th Ftr Gp 12 - F-84D's	:15	"	"	Rocket - Strafe
15	SUPPORT	4th Ftr Gp 12 - F-86's	:10	"	"	Strafe
16	SUPPORT	20th Ftr Gp 16 - F-84D's	:15	"	"	Bomb

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Operation Plan
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AIR OPERATIONS SCHEDULE

D Day Plus 5

SN No	MISSION	ORGANIZATION No A/C and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
17	SUPPORT	4th Ftr Gp 8 - F-86's	:10	As Directed	As Directed	Strafe Phase 1, 2, and 3
18	RECCE	161st Recon 16 - RF-80's	:45	"	"	Tactical Recon. 8 Flights (2 aircraft per Flight)

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Operation Plan
TFAF - 3-50

AIR OPERATIONS SCHEDULE

D-Day Plus 6

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1.	CAP	20th Ftr Gp 4 F-84's	1:30	As Directed	As Directed	Daylight hrs Conditions I
2.	CAP	4th Ftr Gp 4 F-86's	:30	"	"	" "
3.	ESCORT	20th Ftr Gp 12 F-84's	1:30	"	"	Resupply Transports
4.	ESCORT	20th Ftr Gp 12 F-84's	1:30	"	"	" "
5.	STRIKE	34th 35th Bmr Sq 6 B-45's	:10	"	"	Low Level Bombing Enemy Airfields
6.	STRIKE	34th 35th Bmr Sq 6 B-45's	:10	"	"	High Level Bombing Objective Area
7.	STRIKE	20th Ftr G 12 F-84's	:10	"	"	Dive Bombing & Strafing Enemy Airfields
8.	STRIKE	4th Ftr Gp 12 F-86's	:10	"	"	Objective Area
9.	SWEEP	4th Ftr Gp 16 F-86's	:30	"	"	" "
10.	SWEEP	4th Ftr Gp 12 F-86's	:30	"	"	" "
11.	SWEEP	4th Ftr Gp 12 F-86's	:30	"	"	" "
12.	SWEEP	20th Ftr Gp 12 F-84's	1:30	"	"	" "
13.	SUPPORT	34th 35th Bmr Sq 6 B-45's	:10	"	"	High Level Bombing
14.	SUPPORT	20th Ftr Gp 12 F-84's	:15	"	"	Bombing & Strafing
15.	SUPPORT	4th Ftr Gp 12 F-86's	:10	"	"	Strafing
16.	SUPPORT	20th Ftr Gp 12 F-84's	:15	"	"	Dive Bombing

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AIR OPERATIONS SCHEDULE

D-Day Plus 6

MSN No	MISSION	ORGANIZATION No A/c and Type	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
17.	SUPPORT	4th Ftr Gp 8 F-86's	:10	As Directed	As Directed	Str fing
18.	RECCE	161st Recon Sq 16 RF-80's	:45	"	"	Tactical Recon., 8 (2) A/c Flts Phase 1, 2, 3. Targets

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Operation Plan
TF F 3-52

AIR OPERATIONS SCHEDULE

D Day Plus 7, 8, and 9

A.S. No	MISSION	ORGANIZATION No A/C and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1	CAP	20th Ftr Gp 4 - F-84D's	1:30	As Directed	As Directed	Condition I Daylight Hours
2	CAP	4th Ftr Gp 4 - F-86's	:30	"	"	" "
3	ESCORT	20th Ftr Gp 12 - F-84D's	1:30	"	"	Resupply Transport
4	STRIKE	84th 85th Bmr Sq 16 - B-45's	:10	"	"	Bomb Objective Area
5	STRIKE	20th Ftr Gp 16 - F-84D's	:15	"	"	Dive Bomb Objective Area
6	STRIKE	20th Ftr Gp 16 F-84D's	:10	"	"	Strafe Enemy Air Fields
7	SUPPORT	84th 85th Bmr Sq 6 - B-45's	:10	"	"	High Level Bombing of Enemy Air Fields
8	SUPPORT	4th Ftr Gp 8 - F-86's	:10	"	"	Strafe Objective Area
9	SUPPORT	20th Ftr Gp 8 - F-84D's	:15	"	"	Strafe - Dive Bomb Objective Are
10	SUPPORT	20th Ftr Gp 8 - F-84D's	:15	"	"	Dive Bomb Objective Area
11	SUPPORT	20th Ftr Gp 8 - F-84D's	:15	"	"	Rockets - Objective Area
12	SUPPORT	4th Ftr Gp 8 - F-86's	:10	"	"	Strafe Objective Area
13	SWEEP	4th Ftr Gp 12 - F-86's	:30	"	"	Objective Area
14	SWEEP	4th Ftr Gp 12 - F-86's	:30	"	"	" "
15	SWEEP	4th Ftr Gp 12 - F-86's	:30	"	"	" "
16	SWEEP	4th Ftr Gp 8 - F-86's	:30	"	"	" "

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Operation Plan
TF 3-50

AIR OPERATIONS SCHEDULE   D Day Plus 7, 8, and 9

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
17	SWEEP	4th Ftr Gp 12 - F-86's	:30	As Directed	As Directed	Objective Area
18	RECCE	161st Recon 16 -RF-80's	:45	"	"	Phase 1, 2, and 3 Tactical Recon. 8 Flights (2 Aircraft per Flight)

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AIR OPERATIONS SCHEDULE

D-Day Plus 10

MSN No	MISSION	ORGANIZATION No A/c and TYPE	TIME OVER TARGET	UNIT AND CALL TO REPORT TO	RENDEZVOUS	REMARKS
1.	CAP	20th Ftr Gp 4 F-84's	1:30	As Directed	As Directed	Condition I G.C.I. Controlled
2.	CAP	4th Ftr Gp 4 F-86's	:30	"	"	" " "
3.	SWEEP	84th 85th Bmr Sq 16 B-45's	:20	"	With F-84's F-86's RF-80's	Objective Areas
4.	SWEEP	4th Ftr Gp 36 F-86's	:20	"	F-84's RF-80's B-45's	" "
5.	SWEEP	20th Ftr Gp 36 F-84's	:20	"	F-86's RF-80's B-45's	" "
6.	RECCO	161st Recon Sq 12 RF-80's	:30	"	B-45's F-86's F-84's	" "

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Colonel, USAF

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Operation Plan
TFAF No. 3-50

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

APPENDIX II TO ANNEX D

TRAINING

1. General: In order that tactical units participating in exercise SWARMER receive the maximum return for effort expended during the maneuver, it is essential that certain preliminary training objectives be attained prior to the actual maneuver (approximately 21 April 1950).

a. Ground Training:

(1) Schedules of ground training to be accomplished will be prepared by the units for implementation throughout the maneuver period, including an inclement weather schedule.

(2) Training toward fulfilling requirements prescribed by USAF, ConAC, and numbered Air Force Training Directives will be accomplished while in the maneuver area and will be included in the schedules of ground training.

(3) Ground training will emphasize the employment of tactical air power in joint operations. FM 31-35 will be used as a guide.

b. Individual Flight Training: Units will conduct individual training in accordance with existing training directives of ConAC and parent Air Forces. Each unit will submit a detailed training schedule covering the period from date of arrival in the field through 20 April 1950, to reach this headquarters not later than 1 April 1950.

c. A period of approximately six (6) days between 15 and 20 April 1950, will be utilized in conducting unit training as directed by Headquarters, Task Force Air Force, and allowance for this unit training program should be made in the training schedule. (Troop Carrier Force See Annex E). This training will include simulated counter-air, interdiction, and close support of troops. These missions will be controlled by the Joint Operations Center through the Tactical Air Control Center, and will involve coordinated air effort by all participating units. During this period emphasis will be placed on the following types of missions:

(1) Rapid take-off and assembly from dispersed positions.

(2) Offensive-defensive formation tactics.

(3) Simulated attacks against Aggressor air and ground targets.

(4) Accurate navigation and target identification.

(5) Accurate interceptions.

(6) Proficiency in escort and cover tactics.

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(7) Rapid landing of group formation, emphasizing correct spacing.

(8) Correct radio control procedures and discipline.

(9) Ability to accomplish missions prescribed by the JOC.

2. Reports: See Annex K, Reports.

CHESTER L. SLUDER
Colonel, USAF

Authenticated:

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Dep. for Ops.

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Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX III TO ANNEX D

AIR DEFENSE

1. Responsibility: Air defense of U.S.A.F. installations and the maneuver area will be the responsibility of the Commanding General, Task Force Air Force.

a. Aircraft: Sufficient aircraft to adequately defend area will be allocated by the Commanding General, Task Force Air Force.

b. Anti-Aircraft Artillery: One gun battalion and one (1) automatic weapons battalion, AAA, will be assigned to each air base for local defense (Simulated).

2. Areas To Be Defended:

a. MACKALL AIR BASE

b. MAXTON AIR BASE

c. SHAW AIR FORCE BASE

d. LANGLEY AIR FORCE BASE

e. CONGAREE AIR BASE

f. Air Head

g. Transport Resupply Corridors.

3. Control Procedures:

a. Aircraft and Anti-Aircraft Artillery will be controlled by the Joint Operations Center through the Tactical Air Control Center.

b. Until air superiority is gained, combat air patrols will be maintained as required over SHAW, LANGLEY, CAMP MACKALL, MAXTON and CONGAREE AIR BASES. When air superiority is attained, AAA may take over the air defense of the airdromes (Simulated).

c. MAXTON and MACKALL AIR BASES will be protected from air attack by a Gun Defended Area (GDA) and an Inner Artillery Zone (IAZ) in conjunction with Combat Air Patrols (CAP). When control of the air is established, the CAP will be discontinued and defense of the Air Base, other than ground alert, will be the responsibility of the Anti-Aircraft Artillery (Simulated). The 502nd Tactical Control Group will furnish early warning radar cover and Ground Controlled Interception (GCI) from 21 April until end of the exercise.

d. The 502nd Tactical Control Group will furnish the equipment and facilities outlined in Appendix I to Annex F.

e. Flight leaders will report to the TACC at MACKALL AIR BASE upon becoming airborne on all alert missions. All aircraft, while airborne, will remain in contact with the TACC at MACKALL

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AIR BASE for instructions and vectors. Air defense aircraft will maintain contact with this TACC unless control is passed to a TADC or until landing time. All flights will check out with the TACC before departing the area.

4. Reporting and Relieving Procedures:

a. Radio transmission will conform to JANAP 142A, October 1949.

b. A complete list of call signs, frequencies, and channels is contained in Appendix II, Annex F.

c. On routine combat air patrol missions over MACKALL-MAXTON area, the flights will orbit the airdrome outside of the gun defended area. During the period which the objective area is being defended by Combat Air Patrols, JOC will establish the route to be flown for entrance to station. On all missions the flight commander will establish communications with the TACC as soon as possible after take off (See Appendix VII). Upon completion of mission the flight leader will contact the TACC and return to base by prescribed routes. At no time will aircraft leave the target area unless released by the TACC, except in emergency.

d. Procedures prescribed for entry into and exit from the objective area must be adhered to in order to insure proper identification.

5. Air Raid Warning Conditions:

a. Responsibility for prescribing conditions of readiness rests with the Commanding General, Tactical Air Force (Prov), who will normally exercise control through the TACC.

b. Air raid warning conditions and anti-aircraft control colors:

RADIO	MEANING
FLASH RED	Air attack imminent-enemy aircraft in vicinity.
FLASH BLUE	Air attack probable-unidentified aircraft in vicinity.
FLASH WHITE	All clear-aircraft identified as friendly.
CONTROL GREEN	All guns hold fire on air targets unless attacked or positively identified as enemy.
CONTROL YELLOW	All guns fire on any target not positively identified as friendly.

6. Readiness Conditions:

a. Aircraft assigned for the purpose of air defense and interception will be on a standby status in one of the following states of readiness:

(1) Condition One: Flight personnel in possession of latest information of the tactical situation, flight gear on, sitting in aircraft with starting units plugged in, and prepared to be airborne within five (5) minutes after scramble order is given.

(2) Condition Two: Personnel and equipment in readiness to become airborne on fifteen (15) minutes notice.

(3) Condition Three: Personnel and equipment in readiness to become airborne on thirty (30) minutes notice.

7. Anti-aircraft Coordination:

a. The Joint Operations Center will be responsible for AAA coordination in the MAXTON and OUTER CAMP MACKALL area. The Ground Force Commander will be responsible for coordination in the objective area until the TADC (Simulated) is operational.

b. The Commanding Officer of the 20th Fighter Wing will be responsible for coordination in the SHAW AFB-CONGAREE AIR BASE area.

CHESTER L. SLUDER
Colonel, USAF

2 Tabs:
Tab "A" - AAA Control and Employment (Simulated)
Tab "B" - Night Fighter Employment Plan (Simulated)

Authenticated:

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Dep. for Opns.

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Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX III TO ANNEX D

AAA CONTROL AND EMPLOYMENT (SIMULATED)

1. General:

a. Deployment:

(1) Anti-aircraft artillery of the 202nd, 209th and 212th AAA Gun Battalions and the 61st, 62nd and 63rd Automatic Weapons Battalions will be deployed so as to effect maximum protection against hostile air activity at all U.S.A.F. maneuver bases. Deployment of these weapons will be as agreed upon by the Commanding Officer, AAA Group and the Commanding General, Tactical Air Force (Prov).

b. Control:

(1) In accordance with letter Headquarters, USAF, 18 August 1947, Joint Agreement Headquarters, USAF, and Headquarters, US Army, the Commanding General, Task Force Air Force, will assume operational control of AAA units committed to this exercise.

2. Operations:

a. Gun Defended Area: An area, 8,000 yards in radius, surrounding MACKALL and MAXTON AIR BASES will be designated as a gun defended area (GDA).

(1) All aircraft entering and leaving the GDA will be positively identified. To facilitate recognition, all aircraft will enter and leave the GDA by a route and altitude designated by the JOC. Aircraft not positively identified as friendly will be subject to AAA fire.

b. Inner Artillery Zone:

(1) Certain areas within the GDA may be designated as inner artillery zones (IAZ).

(2) Flying over IAZ's at any time and at any altitude is expressly forbidden. Any aircraft flying over an IAZ will be subject to AAA fire without notice.

3. Employment Procedures:

a. Control Relationship:

(1) Control of AAA fire will be effected by the TACC through the Antiaircraft Artillery Operations Room (AAOR).

(2) The TACC and AAA information service (AAAIS) will mutually exchange air raid movement information.

b. Control Conditions: Control conditions of AAA fire will be coordinated through the AAA Liaison Officer. Control conditions will be ordered as follows:

(1) Control Green. Anti-aircraft batteries hold fire.

(2) Control Yellow. Anti-aircraft batteries released for fire.

(3) When individual anti-aircraft batteries are in Control Green and under direct attack appropriate defense measures may be adopted.

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Operation Plan
TFAF No. 3-50

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

APPENDIX III TO ANNEX D

NIGHT FIGHTER EMPLOYMENT PLAN (SIMULATED)

1. Mission: The Night Fighter Units participating in Exercise SWARMER will furnish airborne surveillance and defense at the SHAW, CONGAREE, MAXTON and MACKALL AIR BASES during the periods of darkness from 21 April until D/10. The TACC or TADC will furnish target information to the night fighter patrols while they are within range.

2. Control Procedures:

a. Operational control of the night fighter units will be exercised through the TACC. Aircraft under the control of the TACC or a TADC are required in all cases to follow instructions until released.

b. Aircraft clearing from stations beyond the range of TACC or TADC will contact one of these stations over the predetermined call point.

c. Night fighters will operate quadrant patrols in the general area around MAXTON and MACKALL AB's from sunset to sunrise.

d. Night fighter aircraft will not enter the Gun Defended Area which is bounded by a circle eight thousand (8,000) yards in radius around MAXTON and MACKALL area.

e. General surveillance missions will be conducted between home bases and the maneuver bases in order to harass any enemy missions which might be enroute to the defended area from outlying enemy bases.

f. The night fighter aircraft will be under the control of the TACC or TADC before entering the area and for the duration of the mission.

g. Each replacement aircraft will arrive in the patrol area five (5) minutes prior to the scheduled release time of the aircraft on patrol. No aircraft on patrol duty will return to base prior to being released by the TADC, except in emergency.

Tab "B"

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Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
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APPENDIX IV TO ANNEX D

EMERGENCY PROCEDURES

1. General: This plan prescribes emergency procedures to insure coordinated action in event of emergencies.

2. Control:

a. Paragraph 9a, AFR 20-54 provides that the Area Control Officer of Air Rescue Service is responsible for supervision and operation of rescue activities within his area.

b. Base Commanders:

(1) Commanding Officers of all bases who become cognizant of aircraft in distress will immediately notify the nearest air rescue unit, passing on all information available, such as type of aircraft, point of departure, designation, airspeed, course, altitude and last known position.

(2) All Air Force organizations are responsible for giving all assistance practicable to authorized agencies conducting search and rescue activities, when so requested.

c. Coordination to assist both of the above is essential from Tactical Air Force through the JOC and other facilities which will be available.

d. Release of Information to News Papers: Release to news media of information concerning overdue and missing aircraft will be the responsibility of the commander of the base of departure, or the officer who assumes that responsibility, except that once an aircraft has been declared missing, the commander of the Air Rescue Service activity in charge of the physical search and rescue operations is permitted to release information concerning the progress of search and rescue operations. In all cases the release of information will be in accordance with existing Air Force policies.

3. Reporting Procedures: Instructions contained herein supplement AFR 60-6.

a. Action to be taken by pilots observing an accident or aircraft in distress will be as follows:

(1) Keep aircraft in sight.

(2) Turn on automatic identification equipment, if so equipped.

(3) Report situation through Tactical Air Control System or to any agency that may be contacted.

(4) Follow instructions of TACC or TADC.

(5) Turn off automatic identification when leaving area.

b. Action taken by personnel on the ground observing an accident or aircraft in distress:

(1) Report by phone to nearest base, military installation or JOC.

(2) Describe incident.

(3) Give location.

(4) Give name, rank and AFSN.

(5) Advise of action being taken.

(6) Time of occurrence.

(7) Names of witnesses, if any.

c. Action Taken by Units:

(1) Comply with AF, ConAC, and numbered AF Regulations.

(2) Notify the JOC.

(3) Coordinate search activities with the JOC if a search is required. (This will not be cause for delay if prompt action is indicated by the circumstances).

4. Procedures: Aircraft in distress to follow one of the following procedures:

a. Aircraft Safety Procedure:

(1) When the pilot of an aircraft is uncertain of his position or is expecting a state of emergency, but with the aid of surface stations can proceed on a course, or land at a suitable air field, he will call the surface station using normal procedure.

(2) If the pilot of an aircraft is unable to contact surface stations or does not know what station to call he will use the international safety signal TTT on radiotelegraph (CW) and/or EMERGENCY for radio telephone (Voice).

(3) If the aircraft is unable to contact the ground station, the International Urgent Signals, on radiotelegraph (CW), and/or PAN on radiotelephone (Voice) will be used.

(4) After contact has been established, the pilot will transmit his emergency message which should contain the following information:

(a) Best estimated position and time thereof.

(b) Course, speed and altitude.

(c) Available flight time remaining.

(d) Intention of airplane commander as to ditching, bailing out or crash landing.

b. Aircraft Distress Procedure:

(1) When an aircraft is threatened by serious and imminent danger and requires immediate assistance, the pilot will transmit SOS on CW and/or MAYDAY on voice, giving, if time permits, the information contained in 4.a. above.

5. Aircraft Accident Reporting:

a. Preliminary accident reports will be rendered in accordance with part 3, section 1, of Air Force Regulation 62-14, dated 20 October 1944.

b. Investigating and reporting of aircraft accidents will be as prescribed in AF Regulation 62-14.

(1) In event of an accident, the Commanding General, Task Force Air Force will be notified immediately by TWX, giving all preliminary information. A complete information copy of each accident report will be forwarded to the Commanding General, Tactical Air Force (Prov).

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Operation Plan
TFAF No. 3-50

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N. C.
13 March 1950

APPENDIX V TO ANNEX D

SAFETY AND CONTROL PROCEDURES

1. General: In order to conduct operations SWARMER with a maximum of safety, certain procedures for control and safety are outlined herein.

2. Responsibility: It will be the responsibility of the unit commanders to ascertain that all pilots in their organizations are thoroughly familiar with safety precautions and procedures to be used during this maneuver.

3. Control:

a. Base Commanders will comply with current Air Force Regulations in clearing aircraft and establishing local flying areas.

b. Radar and radio control will be supplied by the 502nd Tactical Control Group for the maneuver area.

c. The maneuver area has been designated a temporary air space reservation and will be closed to all traffic not participating in the exercise, except commercial aircraft flying through the AIR TUNNEL below five thousand (5,000) feet. (See Appendix VII).

d. All aircraft will fly through the corridors extending from operating bases to the objective area.

e. Radio range facilities will be utilized in marginal weather in order to stay within the air space reservation.

4. Safety:

a. No aircraft will enter instrument weather unless properly cleared.

b. No aircraft will fly at an altitude lower than five hundred (500) feet, except when on a specific mission requiring a lower altitude, and in no case will an aircraft fly lower than two hundred (200) feet.

c. Except when flying in formation an aircraft will not approach another closer than one thousand (1,000) feet.

d. An air tunnel across the air space reservation has been established for commercial aircraft. No military aircraft will enter the tunnel below five thousand (5,000) feet altitude.

e. Aircraft flying in different directions, in the air corridors, will conform to Air Force Regulation (60-16) in reference to altitude separation.

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Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N. C.
13 March 1950

Operation Plan
TFAF NO. 3-50

APPENDIX VI TO ANNEX D

OBJECTIVE AREA APPROACH PROCEDURES

1. All aircraft under the control of the Commanding General, Task Force Air Force will utilize the approach lanes shown on the Approach and Reference Chart SWARMER.

2. All SWARMER friendly aircraft approaching the objective area on lane A or B will call the controlling Tactical Air Control Center when over the designated reference point. Lane A, Reference Point, ROCKY MOUNT, N. C., code name TARE. Lane B, Reference Point, HARTSVILLE, S. C., code name DOG.

   a. The following information will be transmitted to the TACC by the Flight or Squadron leader of the particular aircraft involved.

      (1) Call sign of the Flight or Squadron

      (2) Altitude of flight

      (3) Number and type of aircraft

      (4) Type of mission

      (5) Estimated time in target area.

         (a) Example: "Hello, FRISCO this is STEAMER with 16 Eagles, Angels 20, Sweep, 30 minutes".

3. Support aircraft will, upon completion of their mission and after being released by the TACC, return to their base VIA approach lane, at the most economical altitude.

4. No aircraft will enter the target area until cleared by the TACC or TADC.

5. Air Coordinators, Observers and aircraft employed in special missions will make the same report as specified in Par 2.

6. Approach Sectors, Reference and Orbit Points:

   a. Reference Point TARE, (ROCKY MOUNT, N. C.), Lane A, is located at Lat 35°-55' Long 77°-48'.

   b. Reference Point DOG, (HARTSVILLE, S. C.), Lane B, is located at Lat 34°-29' Long 80°-4'.

   c. Reference Point FRISCO, is located at Lat 35°-3' Long 79°-31'. TADC is stationed at this point.

   d. Reference Point CHERRY, (MACKALL AIR BASE) is located at Lat 30°-24' Long 80°-4'.

   e. Reference Point SCARLET, (POPE AIR FORCE BASE), is located at Lat 35°-7' Long 79°-1'.

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f. Reference Point PLUM, (MAXTON AIR BASE), is located at Lat 35°-7' Long 79°-22'.

7. The approach lanes into the objective area will be from five (5) to seven (7) miles wide, and will extend three (3) miles beyond the designated SWARMER Air Bases. (See Appendix VII).

8. Air Bases established within the objective area will be designated by the following names:

a. MACDILL AIR BASE -- CHERRY.

b. POPE AIR FORCE BASE -- SCARLET.

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OPERATIONS PLAN
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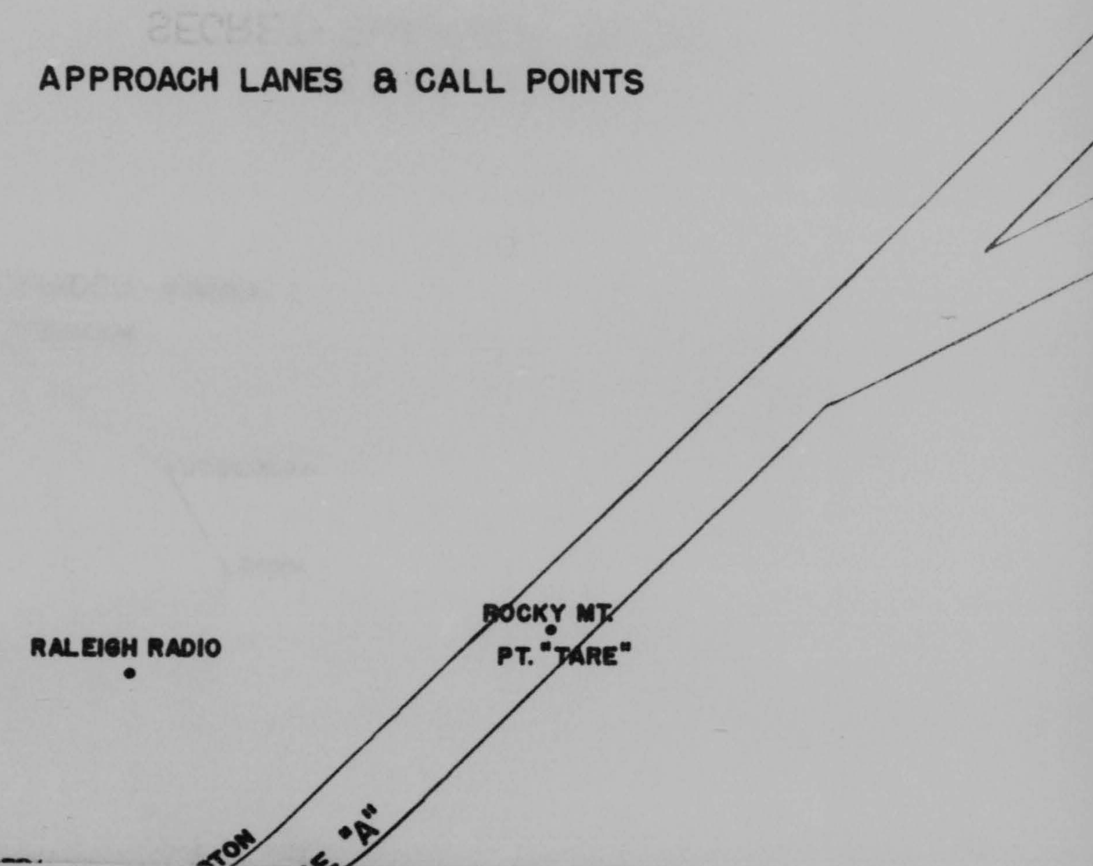
ANNEX "D"
APPENDIX VIII
TAB "A"

APPROACH LANES & CALL POINTS



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ANNEX "D"
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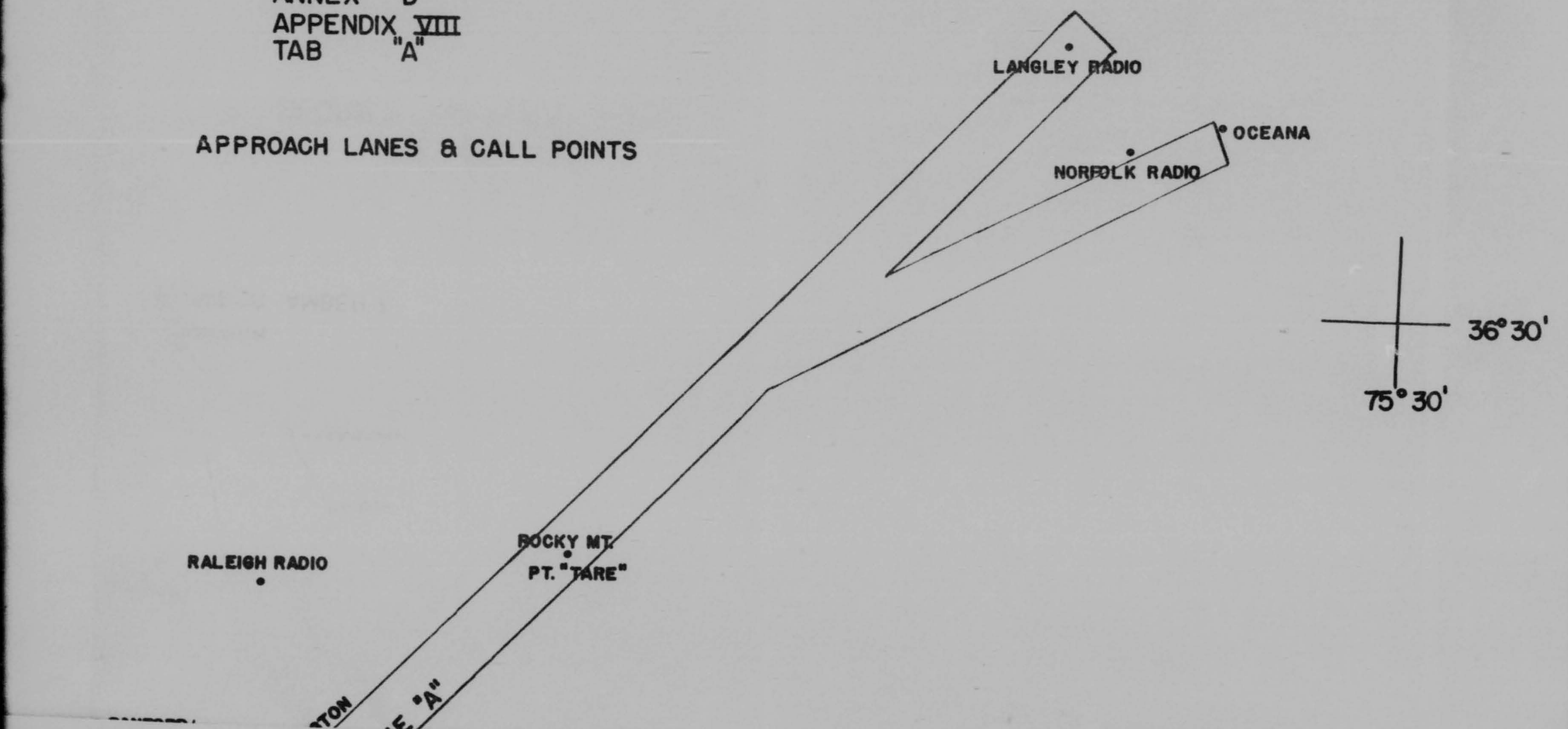

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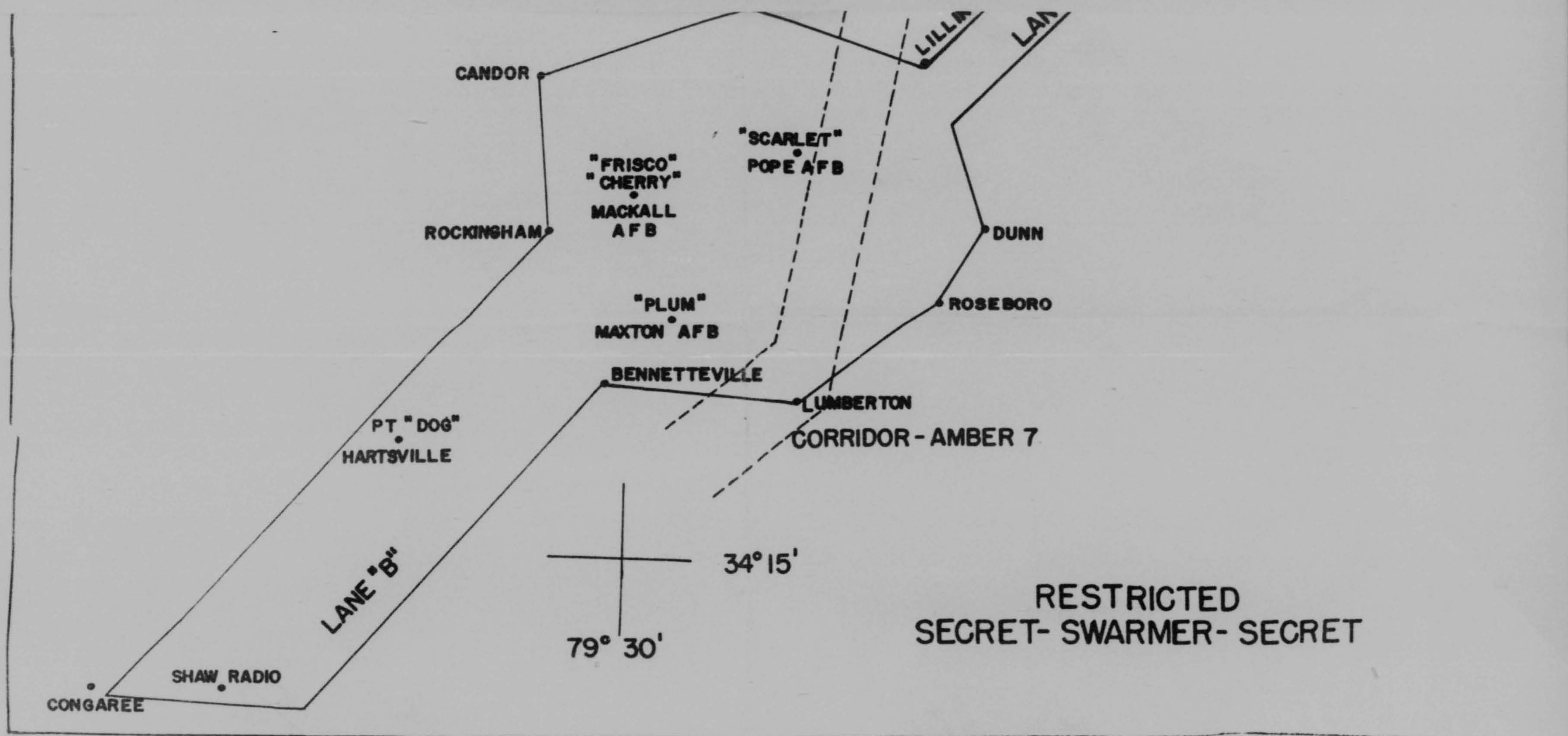

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HEADQUARTERS
TASK FORCE AIR FORCE
EXERCISE SWARMER
POPE AIR FORCE BASE
FORT BRAGG, NORTH CAROLINA

OPERATION PLAN
TFAF No. 3-50

ANNEX E

TROOP CARRIER PLAN

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"Headquarters, Task Force Air Force"
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

ANNEX E

TROOP CARRIER PLAN

1. Task Organization: All Troop Carrier and Transport aircraft participating in exercise "SWARMER" will be organized into a Troop Carrier Force. All aircraft referred to herein as Troop Carrier will include MATS aircraft. (See Annex "A", Task Organization)

2. Mission: The Troop Carrier Force will provide the airlift necessary to initiate a corps-size airhead on D-day and accomplish the subsequent airhead build-up from D thru D + 10 by accomplishing the following tasks:

a. Airlift four (4) RCT of the 82nd and 11th Airborne Divisions from MAXTON AIR BASE, N. C., SHAW AIR FORCE BASE, S.C. and CONGAREE AIR BASE, S. C. to be air dropped into the assult area in vicinity of FORT BRAGG, N. C. (See Appendix I, Airborne Planning Data)

b. Air lift one (1) RCT of the 11th Airborne Division from CAMP CAMPBELL, KY., for air landing at MACKALL AIR BASE, N. C.

c. Air lift Division troops of 82nd and 11th Airborne Divisions to MACKALL AIR BASE, N. C.

d. Air lift 3rd Infantry Division (CPX) to MACKALL AIR BASE, N.C.

e. Air lift supporting elements and service troops of V Corps to MACKALL AIR BASE, N. C.

f. Air lift TFAF elements to MACKALL AIR BASE, N. C. as follows:

(1) One (1) Fighter Wing (Simulated)

(2) One (1) Reconn. Squadron (Simulated)

(3) Control elements

(4) Service elements

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g. Air lift other Army elements as required by V Corps to MACKALL AIR BASE, N. C.

h. Air lift the replacement and reserve personnel required by V Corps for expansion of airhead to MACKALL AIR BASE, N. C.

i. Air lift to MACKALL AIR BASE, N. C. the equipment and supplies necessary for TFAF, V Corps and Carolina Base Section to conduct operation in the airhead from D-day thru D+10.

3. Tasks for subordinate Units:

a. The Troop Carrier Force will:

(1) Control and operate all troop carrier aircraft participating in the maneuver, based on allocations contained in Appendix II, Aircraft Allocation Schedule.

(2) Provide Liaison Officers to the 82nd and 11th Airborne Divisions to coordinate details of airlift of those units.

(3) Provide necessary personnel to man the TFAF movements Section (See Appendix II, Annex A). This section will be located at Headquarters, TFAF and personnel will be in place by 18 April 1950.

(4) Prepare detailed schedule of missions for period D thru D+10 for all troop carrier aircraft, containing information outlined in Appendix III, Chronological Schedule of Missions Chart and submit information copies to Hq, TFAF prior to 15 April 1950

(5) Provide an Air Field Control Party to coordinate landing, parking and off-loading of all aircraft in the airhead in conformance with Appendix IV, Landing, Take-off and Parking Patterns.

(6) Provide all participating troop carrier units with detailed instructions regarding flying operations and aircraft handling in the air head.

(7) Furnish Hq TFAF by 1800 hours (EST) daily, effective 20 April, with number of aircraft by type available for the following day.

(8) Furnish Hq TFAF, prior to 1 April, with detailed schedule of training from date of arrival in the maneuver area through 20 April for all participating troop carrier units.

b. The 314th Troop Carrier Wing will:

(1) Provide the commander for the Troop Carrier Force to be located at MAXTON AIR BASE, N. C.

(2) Provide personnel for the staff of the Headquarters, Troop Carrier Force as directed by the Commanding General, Troop Carrier Force.

(3) Provide six (6) Troop Carrier Squadrons to airlift personnel, supplies and equipment for the initial airborne assault and the airhead build-up.

(4) Insure that necessary coordination between the fighter unit and troop carrier units has been achieved on the use of MAXTON AIR BASE so that both units will be able to fulfill their commitments. Maneuver Base - MAXTON AIR BASE, N. C.

c. The 62nd Troop Carrier Wing will:

(1) Provide Personnel for the staff of the Headquarters, Troop Carrier Force as directed by the Commanding General, Troop Carrier Force.

(2) Provide one (1) Troop Carrier Squadron to airlift personnel, supplies and equipment into the air head as directed by the Commanding General, Troop Carrier Force. Maneuver Base - CONGAREE AIR BASE, S. C.

d. The Military Air Transport Service will:

(1) Provide personnel for the staff of the Headquarters, Troop Carrier Force as directed by the Commanding General Troop Carrier Force.

(2) Provide one hundred (100) C-54 aircraft to airlift personnel, supplies and equipment into the air head as directed by the Commanding General, Troop Carrier Force. Maneuver Base-CONGAREE AIR BASE, S. C.

e. United States Air Force Reserve Troop Carrier Units will:

(1) Provide personnel as requested by the Commanding General Troop Carrier Force to coordinate details of Reserve airlift.

(2) Provide thirty six (36) C-46 aircraft to airlift personnel, supplies and equipment into the air head on 29-30 April and 1-2 May as directed by the Commanding General, Troop Carrier Force. Maneuver Base - SHAW AFB, S. C.

4. General Instructions:

a. All paradrop and aerial resupply missions will utilize C-82 and/or C-119 aircraft.

b. All troop carrier operations will be carried out in conformance with troop carrier SOPs.

c. The allocation of airlift by tonnages will be made by the Maneuver Commander and aircraft for the movement of personnel, supplies and equipment will be allocated by Hq. TFAF to the T Troop Carrier Force. (See Appendix V, Flow Chart of Logistical Movement Control).

d. Loading, lashing, unlashing and unloading of all supplies and equipment in and from troop carrier aircraft will be a function of the Port Companies assigned the Carolina Base Section; however, in no manner does this relieve the pilot from the responsibility for final approval of the loading and lashing in his aircraft.

Chester L. Sluder

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Colonel, USAF

Appendices:
- I - Airborne Planning Data.
- II - Aircraft Allocation Schedule.
- III - Chronological Schedule of Missions Chart.
- IV - Landing, Take-off and Parking Patterns.
- V - Flow Chart of Logistical Movement Control.

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"Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

APPENDIX I TO ANNEX E

AIRBORNE PLANNING DATA

Departure Airfields	Army Units	Jump Troops	Air land Troops	Total
Camp Campbell Congaree Shaw	11th ABN DIV (2 RCT + Div Trps)	2,000	3,500	5,500
Maxton	82nd ABN DIV (3 RCT + Div Trps)	6,000	2,000	8,000

Grand Total 13,500

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Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.

APPENDIX II TO ANNEX E

Operation Plan
TFAF No. 3-50

AIRCRAFT ALLOCATION SCHEDULE

1. Date	2. Aircraft Allocated to V Corps	3. Sorties	4. Aircraft Allocated to Carolina B/ Section	5. Sorties	6. Aircraft Allocated to TFAF	7. Sorties	8. Staging Bases	9. Aircraft Loads	10. Remarks
D-Day	25 C-119's 32 C-82's 74 C-54's	3 3 1			3 C-82's	3	Maxton-Shaw Congaree Cp Campbell	Personnel Supplies & Equip- ment	Aircraft allocat are operational aircraft.
D Plus 1	25 C-119's 35 C-82's 74 C-54's	2 2 2	25 C-119's 35 C-82's 74 C-54's	1 1 1			Maxton-Shaw Congaree	"	
D Plus 2	25 C-119's 35 C-82's 74 C-54's	2 2 2	25 C-119's 35 C-82's 74 C-54's	1 1 1			"	"	
D Plus 3	25 C-119's 35 C-82's 74 C-54's	2 2 2	25 C-119's 35 C-82's 74 C-54's	1 1 1			"	"	
D Plus 4	25 C-119's 35 C-82's 74 C-54's	1 1 2	25 C-119's 35 C-82's 74 C-54's	2 2 1			"	"	
D Plus 5	25 C-119's 35 C-82's 74 C-54's	1 1 1	25 C-119's 35 C-82's 74 C-54's	2 2 2			"	"	

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Operation Plan
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1. Date	2. Aircraft allocated to V Corps	3. Sorties	4. Aircraft allocated to B/Section	5. Sorties	6. Aircraft allocated to TFAF	7. Sorties	8. Staging Bases	9. Aircraft loads	10. Remarks
D Plus 6	25 C-119's 35 C-82's 74 C-54's	1 1 1	25 C-119's 35 C-82's 74 C-54's	2 2 2			Maxton Shaw Congaree	W/Pers, Sup/Equip	
D Plus 7	25 C-119's 35 C-82's 74 C-54's	1 1 1	25 C-119's 35 C-82's 74 C-54's	2 2 2			"	"	
D Plus 8	25 C-119's 35 C-82's 74 C-54's	1 1 1	25 C-119's 35 C-82's 74 C-54's	2 2 2			"	"	
D Plus 9	25 C-119's 35 C-82's 74 C-54's	1 1 1	25 C-119's 35 C-82's 74 C-54's	2 2 2			"	"	
D Plus 10	25 C-119's 35 C-82's 74 C-54's	1 1 1	25 C-119's 35 C-82's 74 C-54's	2 2 2			"	"	

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Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

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TROOP CARRIER EMPLOYMENT PLAN

APPENDIX III TO ANNEX E

CHRONOLOGICAL SCHEDULE OF MISSIONS CHART

Serial No.	Unit Designation	No. and Type Aircraft	Load	Departure Base	Approx Time of Departure	Time Over CDP	Time Over RDV Pt.	Time Over OBJ	Objective	Remarks

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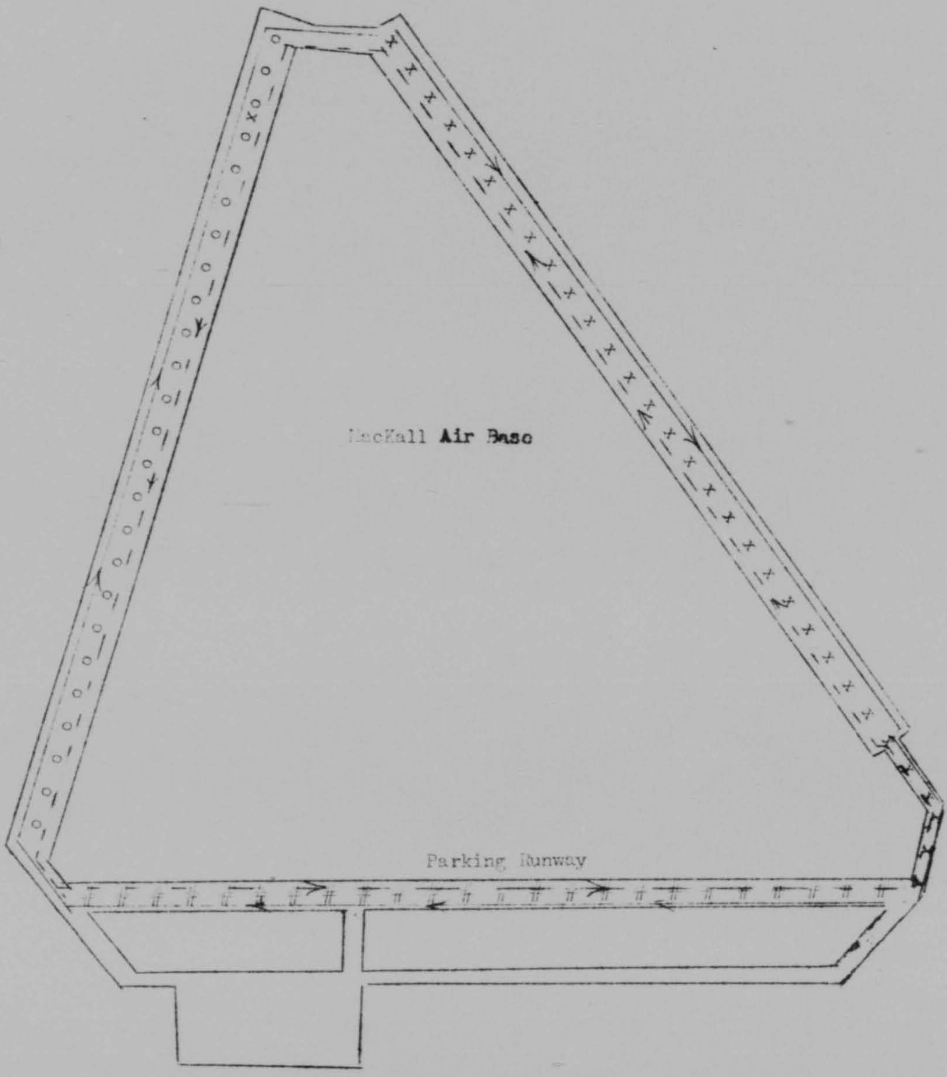
APPENDIX IV TO ANNEX E

LANDING - TAKE-OFF AND PARKING PATTERNS

Pattern Able		Pattern Baker	
Land and Take-off	o—o—o	Land and Take-off	o--o--o
Taxi	x—x—x	Taxi	x--x--x
Park to unload	#—#—#	Park to unload	#--#--#



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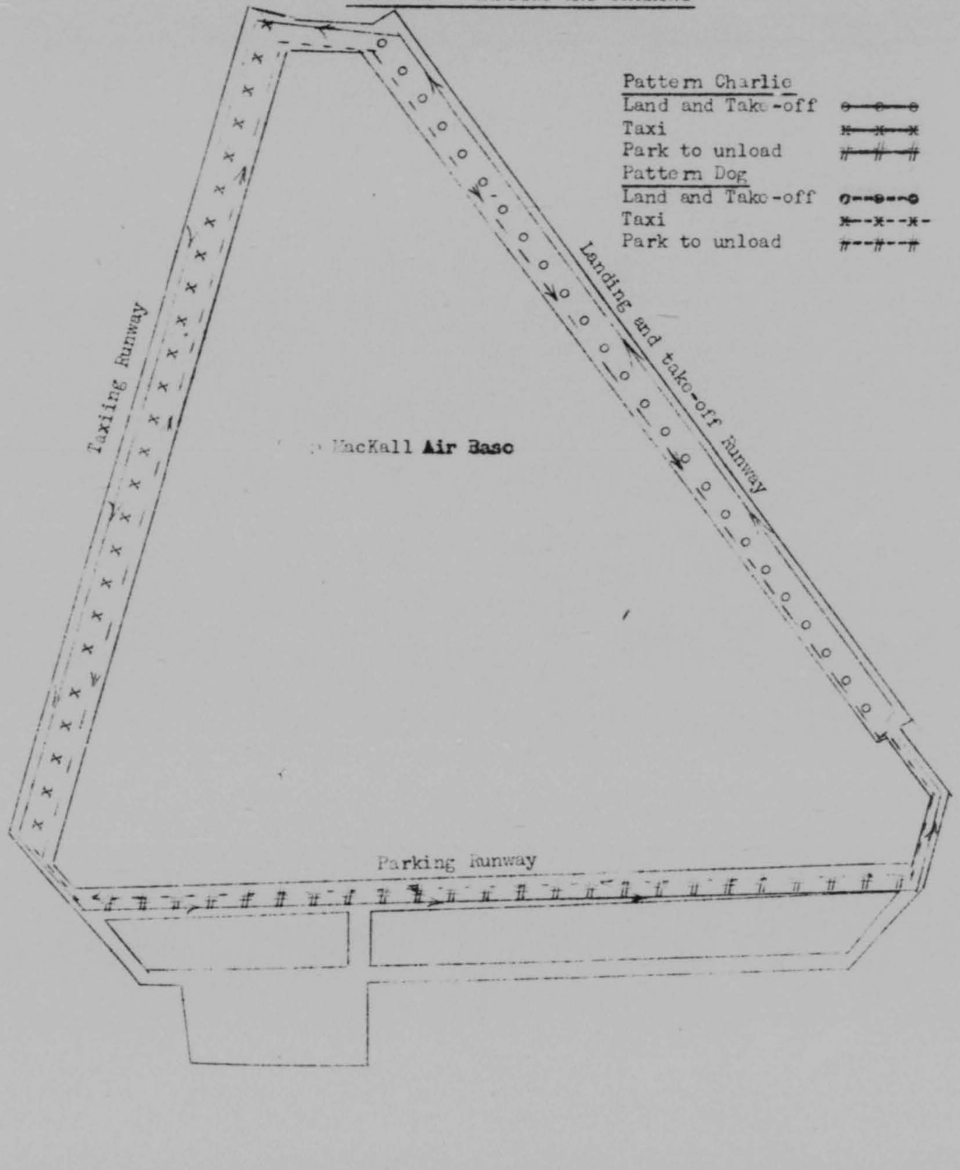
APPENDIX IV TO ANNEX E

TAKE-OFF - LANDING AND PARKING



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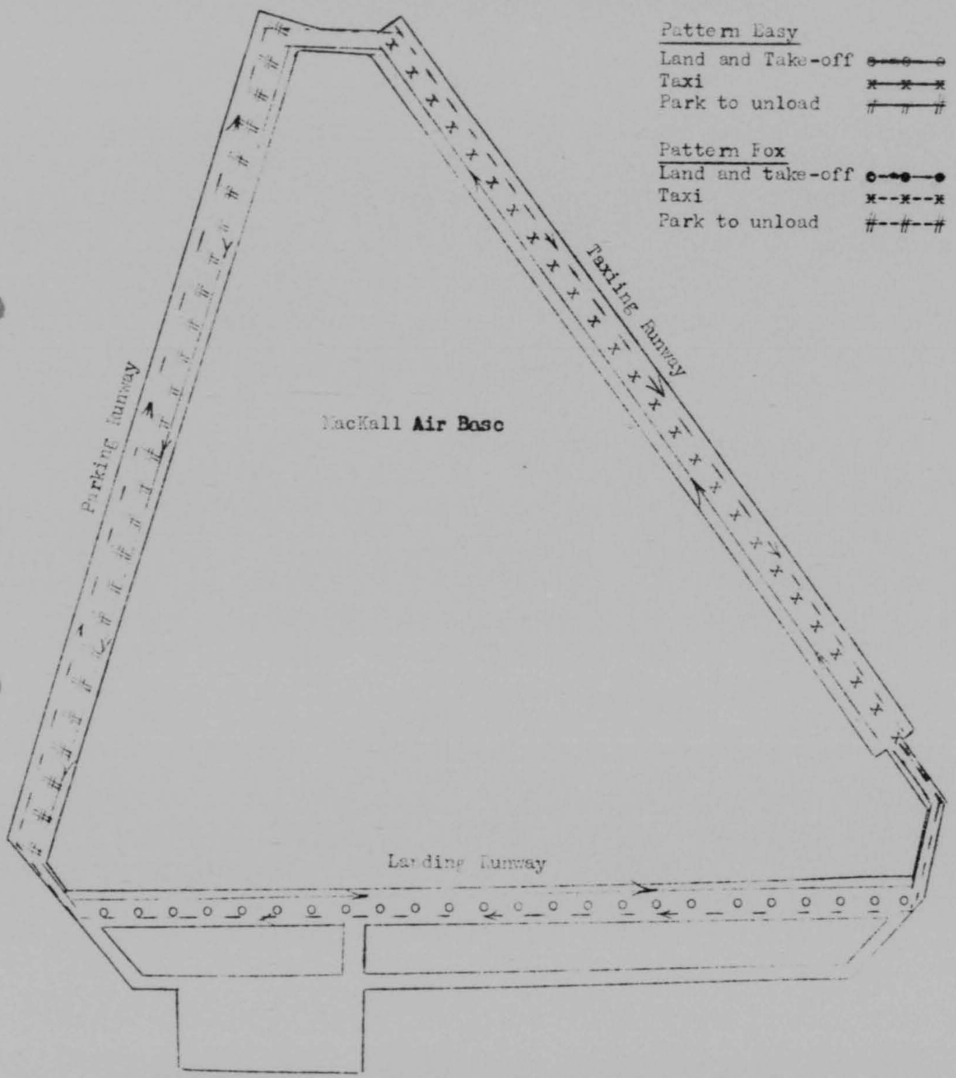
APPENDIX IV TO ANNEX E

LANDING - TAKE-OFF AND PARKING



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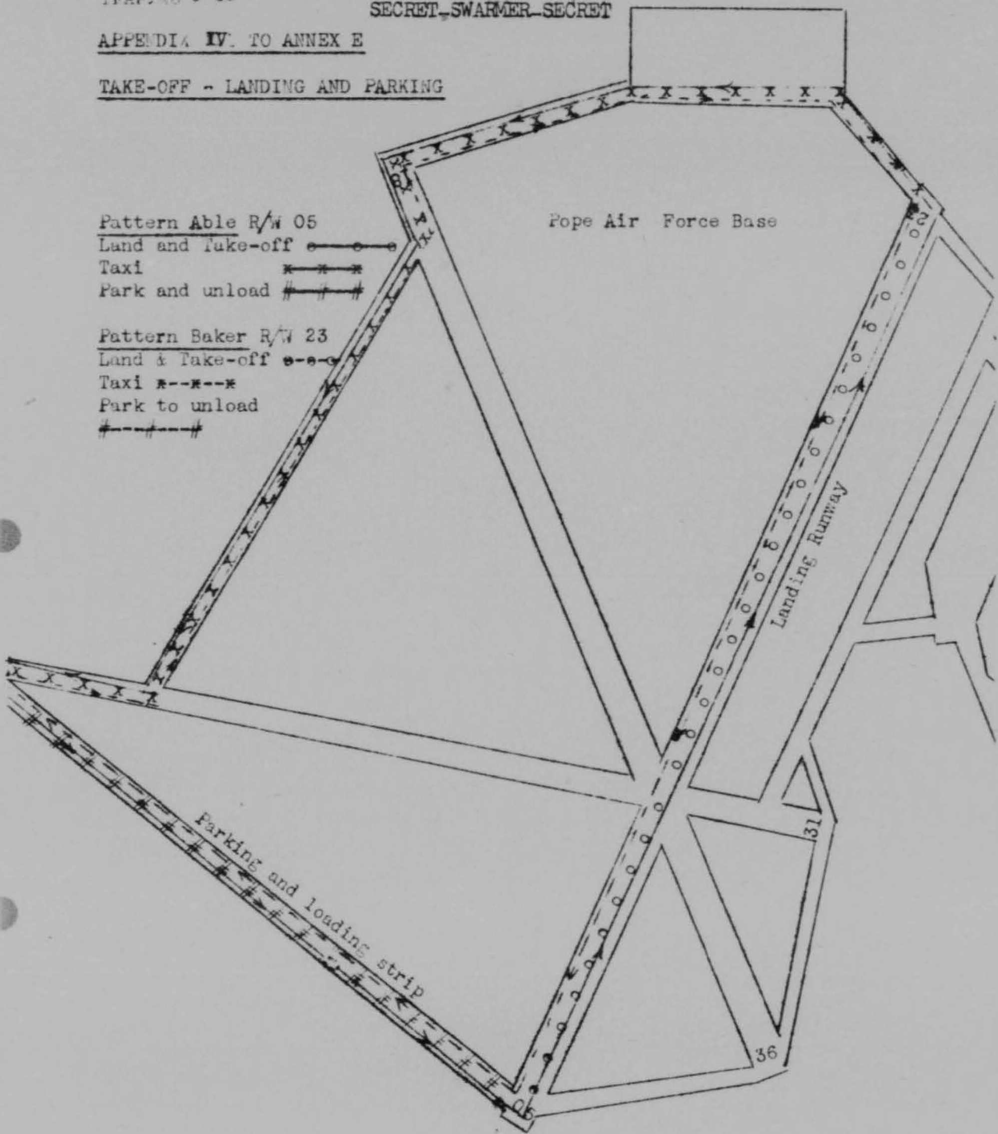
TAKE-OFF - LANDING AND PARKING



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Operation Plan
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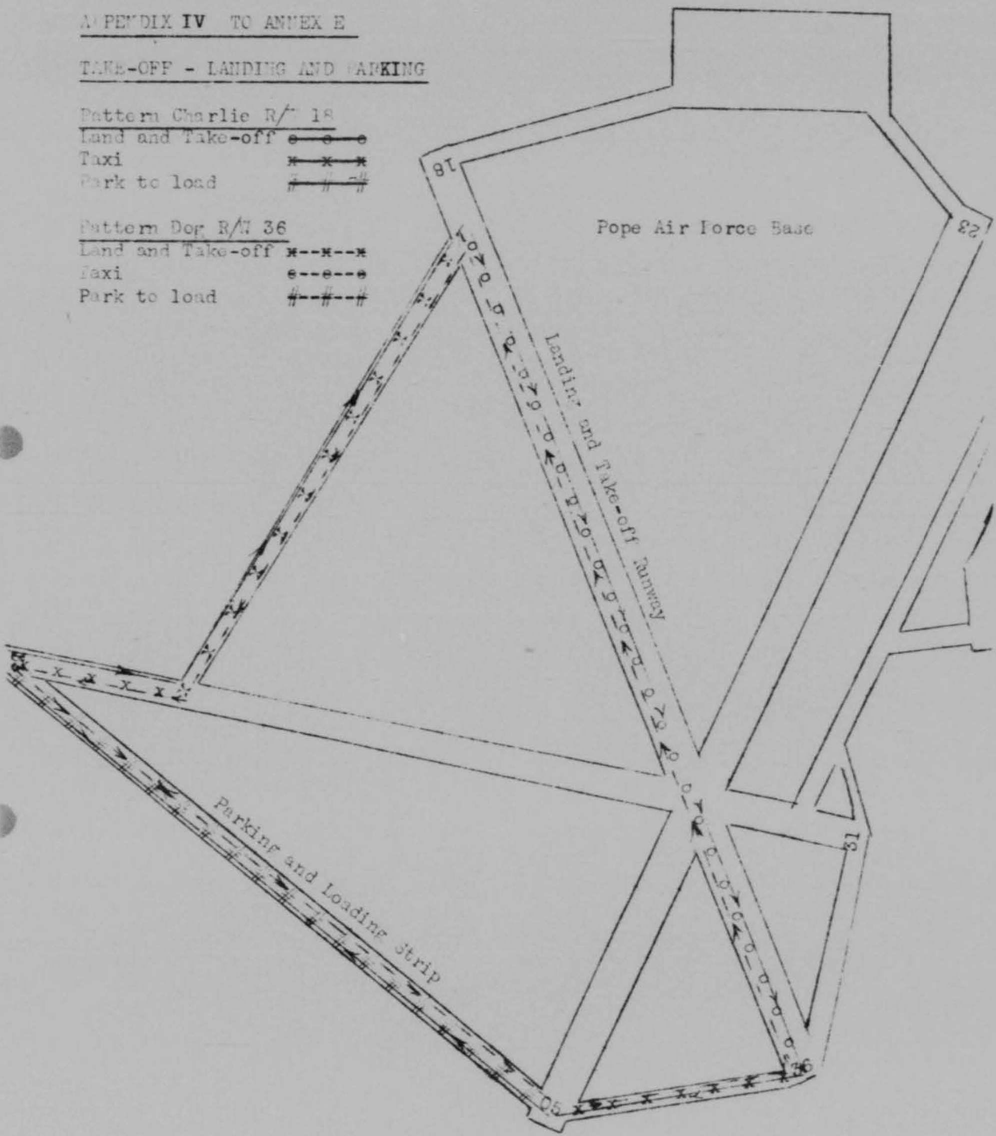
APPENDIX IV TO ANNEX E

TAKE-OFF - LANDING AND PARKING

Pattern Charlie R/W 18
Land and Take-off e—e—e
Taxi x—x—x
Park to load #—#—#

Pattern Dog R/W 36
Land and Take-off x--x--x
Taxi e--e--e
Park to load #--#--#

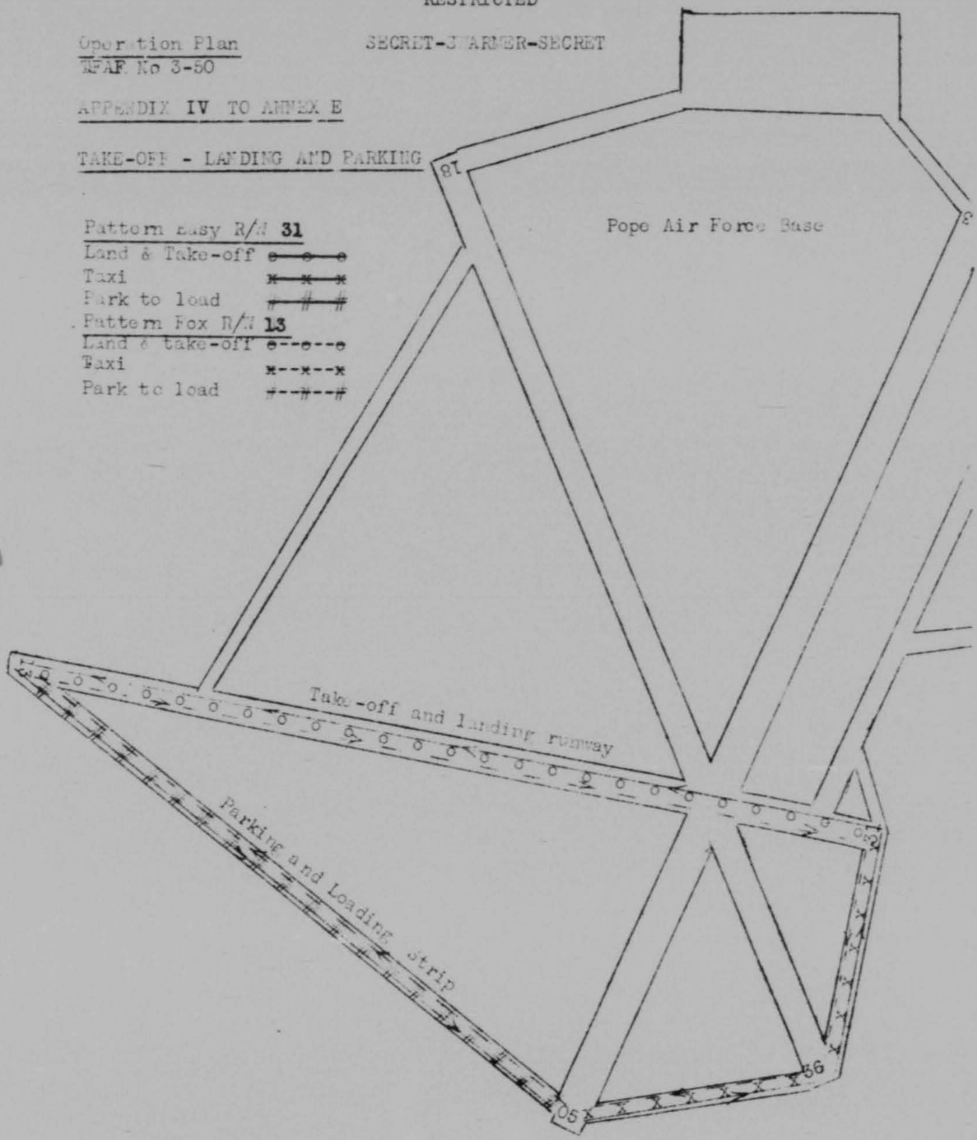


Operation Plan
TAF No 3-50

APPENDIX IV TO ANNEX E

TAKE-OFF - LANDING AND PARKING

Pattern Easy R/W 31
Land & Take-off o—o—o
Taxi x—x—x
Park to load #—#—#
Pattern Fox R/W 13
Land & take-off o--o--o
Taxi x--x--x
Park to load #--#--#



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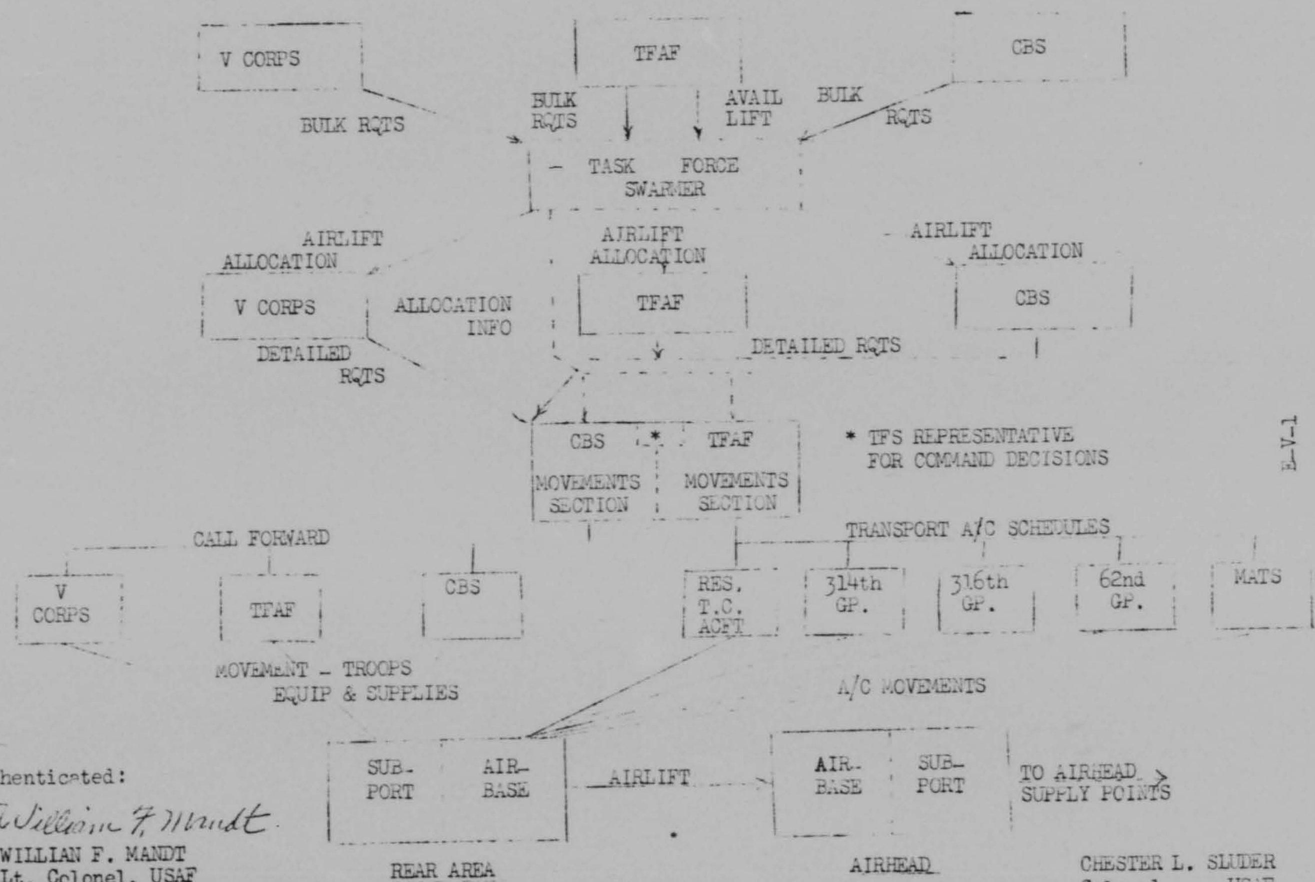
APPENDIX V to ANNEX E

FLOW CHART OF

LOGISTICAL MOVEMENTS CONTROL



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HEADQUARTERS
TASK FORCE AIR FORCE
EXERCISE SWARMER
POPE AIR FORCE BASE
FORT BRAGG, NORTH CAROLINA

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ANNEX F

COMMUNICATIONS-ELECTRONICS

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Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

ANNEX F

COMMUNICATIONS - ELECTRONICS

1. GENERAL INSTRUCTIONS.

a. Communications-Electronics systems and facilities to be established in support of Tactical Air operations, for Exercise SWARMER, will conform generally to those set forth in FM 31-35.

b. Establishment of normal Command, Administrative, and Operational nets, both wire and radio, will be in conformance with standard operating procedures of a Tactical Air Force.

c. All usage of communication-electronic equipment will be in accordance with procedures set forth in current JANAP's and CCBP's.

d. Encryption of messages will be in accordance with Traffic Security Plan as established by Headquarters Exercise SWARMER and issued as appendix to this annex.

e. All participating communications personnel will be thoroughly briefed in all phases of the air operations and the contributing communications networks.

f. Radio-telephone procedures will be in accordance with JANAP 125. Telegraph procedures will be as set forth in CCBP-1.

g. Conditions relative to safety of life or aircraft will automatically terminate restrictions imposed by maneuver regulations as to radio silence. All communication facilities will be placed at the disposal of the unit concerned to facilitate rescue operations.

h. This annex, and appendices, is effective upon receipt for planning, and effective for operations concurrently with Air Operations Plan No. 3-50, Headquarters, Task Force Air Force.

2. RADIO.

a. Task Force Air Force radio nets to be established in support of Air Force operations during Exercise SWARMER will be in accordance with Command, Administration and Operational requirements. They will consist of:

(1) Tactical Air Command, Command net:

(a) Headquarters, Tactical Air Command.

(b) Headquarters, Fourteenth Air Force.

(c) Headquarters, Tactical Air Force (Prov) Advance.

(d) Headquarters, Tactical Air Force (Prov) Rear.

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(2) Task Force Air Force, Command net:

(a) Headquarters, Tactical Air Force (Prov) Advance.

(b) Headquarters, 20th Fighter Bomber Wing.

(c) Headquarters, Tactical Bomber Force.

(d) Headquarters, Troop Carrier Force.

(3) Tactical Air Force Liaison (Air Ground):

(a) Headquarters, Tactical Air Force (Prov) Advance.

(b) Commander Airborne Troops (In Flight).

(4) Tactical Air Force HF RTTY Net:

(a) Headquarters, Tactical Air Force (Prov) Advance.

(b) Headquarters, Tactical Air Command.

(5) TACC - Tactical Control Net:

(a) TACC.

(b) TADC's.

(c) TACP's.

(6) TACC - Teller Net:

(a) TACC.

(b) TADC's.

(7) For detailed outline and schematic diagrams of complete air ground, point to point net works, see Appendix V, this Annex.

b. Radio Frequency Plan.

(1) See Appendix II, this Annex.

c. Radio Call Signs.

(1) Radio call signs are contained in Appendix III, this Annex.

d. Radio Procedure and Discipline.

(1) Organization Commanders will exercise strict supervision to insure that their stations in the radio nets are operated in accordance with approved procedures to the end that traffic is cleared efficiently, accurately, and rapidly. Serious offenses against circuit discipline or repeated failure to conform to prescribed procedure, either CW or Voice, will be noted by the Umpire who will take appropriate action in each case.

(2) Joint and combined R/T procedure is set forth in JANAP 125.

3. RADAR.

a. Radar facilities will be sited and employed in accordance with applicable Technical and Field Manuals for each type Radar, and in accordance with Tactical Air Force Doctrines.

4. TACTICAL COMMUNICATIONS.

a. Tactical communications network of radio, telephone, and wire will be established as required to provide necessary inter-communications linking TACP's TADC's and TACC of the 502nd Tactical Control Group in accordance with Standard Operating Procedures of that unit.

b. Air-Ground facilities of ground control will be as required to provide necessary aircraft control.

5. NAVIGATIONAL AIDS.

a. Standard AACS navigational aids consisting of; Tower Control Communications; Ground Control Approach System; Homing Beacons; Interphone Communication Services, and Aircraft Control Communication Networks, will be provided at, and between each Air Base occupied by Task Force Air Force units. Responsibility for installation, operation and maintenance for these facilities is held by Detachments of the 1850th Mobile Communications Squadron, (AACS).

6. AIR RAID WARNING.

a. Air Raid Warning services for Headquarters, Task Force Air Force, Headquarters, United States Ground Forces, and all subordinate units within the Task Force Air Force Area of responsibility, will be the function of the JOC. Operational channels will be utilized by the JOC for air warnings as required.

7. WEATHER.

a. Weather service for Headquarters, Task Force Air Force, and all subordinate units will be the responsibility of Detachments of the 2060th Weather Squadron in accordance with Standard Air Weather Service procedures and practices for air base operations. Communications for weather services will be a function of the AACS communications facilities as provided each base.

8. INTELLIGENCE COMMUNICATIONS.

a. Communications facilities for the collection and dissemination of intelligence data will be provided through normal operational channels as furnished to the JOC under provisions of the General Communications Plan.

9. WIRE COMMUNICATIONS.

a. Radio voice tactical calls will be used to designate unit switching centrals. The words "Rear, Main, Advance, etc." may be added to designate appropriate echelons.

b. Teletype-Radio CW tactical calls will be used to designate unit headquarters.

c. Responsibility-See Appendix I, this Annex.

10. VISUAL COMMUNICATIONS.

a. All flying personnel will be thoroughly familiar with hand and other forms of visual signaling and make maximum use of same to alleviate overloading of aircraft tactical circuits.

b. CCBP-8 will be the code governing use of air panels.

11. COMMUNICATIONS FAILURE.

a. Failure in communications, whether equipment or personnel, will be reported to this command in writing stating deficiency, cause and corrective action instigated.

12. COMMUNICATIONS SECURITY.

a. Codes, Ciphers, and Crypto-Aids.

(1) Cryptographic instructions are contained in Appendix VIII, this Annex.

(2) CCBP-8 will govern the use of Air Panels.

b. Authentication.

(1) Authentication systems are contained in Appendix VIII, this Annex.

c. IFF Code Assignments.

(1) See Appendix IX, this Annex.

13. UNIT RESPONSIBILITIES.

a. See Appendix I, this Annex.

14. ELECTRONIC COUNTERMEASURES (ECM).

a. Electronic countermeasures will be controlled at the Umpire level.

b. All communications and radar activities should be alert to the possibilities of the enemy's use of electronic countermeasures.

c. Electronic countermeasures are not to be employed in a manner which will jeopardize the safety of any unit or aircraft by confusing its safe maneuver or deceiving it into a dangerous situation.

d. Electronic countermeasures are not to be employed to the extent where it will seriously confuse operating forces or impede the main objective of joint tactical and operational training. They are to be utilized only for short periods not to exceed ten (10) minutes and not more than once each hour perspecific circuit.

e. Active communications countermeasures will not be employed.

f. Neutral circuits such as Maneuver Commander, Umpire, Press, Civilian, Search and Rescue, etc. will not be subjected to electronic countermeasures.

g. Aids to air navigation such as Instrument Landing System (ILS), Ground Control Approach (GCA), Beacons, and Glide Path Frequencies will not be subjected to electronic countermeasures.

15. REFERENCE PUBLICATIONS.

a. FM 31-35.

b. TB-SIG-5.

c. TB-SIG-54.

d. AF Manual 100-25.

e. AFL-AFOIR 311.5 dated 3 mar 49, Security of Airborne Reconnaissance Operations.

f. AFL-AFQAC-311 dated 10 Feb 49, Joint Electronic Countermeasures Policy.

16. TIME.

a. Instructions relative to time are contained in JANAP's 121 and 144.

b. A date time group or time group will be used on all messages and all signal or voice radio transmission when a later reference may be required.

c. Message reference will be made by use of the originators abbreviated title plus the date-time group of the message; e.g., CGAFF 121343Z. This stipulation does not preclude the additional use of internal serial numbers if considered essential.

d. Zebra time will be used for message date time groups.

e. Local Zone time plus Zone designation applies for operations.

NOTE: In the event of an actual emergency, the Exercise Commander will send to all units "Exercise Terminated". Upon receipt of this message, each unit shall:

1. Terminate exercise conditions.

2. Place all communications in standby status, clear channels of exercise traffic and await instructions as to emergency requirements.

Chester L. Sluder

CHESTER L. SLUDER
Colonel, USAF

Appendices:

I - Unit Responsibilities

II - Radio Frequency Plan

III - Radio Call Signs

IV - Tactical Control Communications System

V - Command Administrative Nets

VI - Telephone and Teletype Systems.

VII - Command HF and FM Circuit Usage

VIII - Cryptographic and Authentication Systems

IX - IFF Doctrine

X - Time Signals

XI - Time Zones

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX I TO ANNEX F

UNIT RESPONSIBILITIES

1. Specific unit communications responsibilities for the implementation of the operation plan are as follows:

a. 502nd Tactical Control Group:

(1) In the Headquarters, Tactical Air Force (Prov) Advance area:

(a) Install, maintain and operate one (1) TACC.

(2) In the MAXTON AIRBASE area:

(a) Install, maintain and Operate one (1) TADC-H.

(3) In the CANDOR area:

(a) Install, maintain and operate one (1) TADC-LW

(4) In the V Corps area MACKALL AIRBASE:

(a) Install, maintain and operate six (6) TACP's.

(5) In the SANDSTONE HILL area (FORT BRAGG):

(a) Install, maintain and operate one (1) GCI (Ground Control Intercept Station).

(6) Provide personnel and equipment to establish communication nets for ground control of aircraft and point to point inter-communications systems between TACC, TADC and TACP's. These nets will be as required to implement the tactical mission of the 502nd Tactical Control Group in providing early warning, aircraft control and facilitate tactical air operations in support of Ground Forces.

(7) Frequencies and unit call signs to be employed by the Task Force Air Force units will be published by Headquarters Exercise SWARMER and will be as indicated in Appendix II & III, this Annex.

b. The 934th Signal Bn (Sep Tac):

(1) Install, operate and maintain the following facilities in the CAMP MACKALL area:

(a) One (1) Auto Manual Swbd, 100 phone service at Headquarters, Tactical Air Force (Prov) Advance.

(b) Terminals for Telephone trunk service from Tactical Air Force (Prov) Advance Swbd as follows:

Three (3) to MANCOM Swbd.

Six (6) to V Corps Headquarters Swbd.

(c) Terminals for Simplex TTY service from Headquarters, Tactical Air Force (Prov) Advance to:

LANGLEY AIR FORCE BASE Operations.

CONGAREE AIRBASE Operations.

SHAW AIR FORCE BASE Operations.

MAXTON AIRBASE Operations.

(d) Terminals for Simplex TTY trunk service from Headquarters, Tactical Air Force (Prov) Advance Swbd to MANCOM Swbd.

Two (2) to V Corps Headquarters Swbd.

(e) Terminal for Duplex TTY service (RTTY) from Headquarters, Tactical Air Force (Prov) Advance to Headquarters, Tactical Air Command, LANGLEY AIR FORCE BASE.

(f) Terminals for private line Service (Telephone) from JOC as follows:

One (1) to LANGLEY AIR FORCE BASE Operations.

One (1) to CONGAREE AIRBASE Operations.

One (1) to SHAW AIR FORCE BASE Operations.

One (1) to MAXTON AIRBASE Operations.

(g) Terminals for HF/RT net to include the following stations.

LANGLEY AIR FORCE BASE.

CONGAREE AIRBASE.

SHAW AIR FORCE BASE.

MAXTON AIRBASE.

Headquarters, Fourteenth Air Force.

Headquarters, Tactical Air Command, LANGLEY AIR FORCE BASE.

(h) Provide CW net terminal NCS at Headquarters, Tactical Air Force (Prov) Advance to include the following stations:

LANGLEY AIR FORCE BASE.

CONGAREE AIRBASE.

SHAW AIR FORCE BASE

MAXTON AIRBASE.

(1) Communications Center, to include:

Message Center.

Crypto Center.

Traffic Center.

(2) Commercial facilities required for above commitments will be arranged for by this Headquarters. All other equipment will be furnished by the 934th Signal Bn (Sep Tac).

(3) Frequencies for radio circuits are contained in Appendix II, this Annex.

(4) Crypto and Authentication Systems to be used will be found in Appendix VIII, this Annex.

c. Base Commanders.

(1) Base Commanders of LANGLEY, CONGAREE, SHAW and MAXTON AIR FORCE BASE, will be responsible for installation, operation and maintenance of terminal communications facilities for all Combat Forces, USAF (Friendly) which are assigned or otherwise attached to their bases during Exercise SWARMER to include:

(a) One (1) terminal for Telephone trunk service to Tactical Air Force (Prov) Advance Swbd.

(b) One (1) terminal for Simplex TTY service from base operations to Tactical Air Force (Prov) Advance Swbd.

(c) One (1) terminal for Private Line service (Telephone) to JOC.

(d) One (1) terminal for HF/RT loop or trunk service to Tactical Air Force (Prov) Advance Swbd.

(e) Net CW Station to Tactical Air Force (Prov) Advance.

(f) Communications Center to include:

Message Center.

Crypto Center.

Traffic Center.

(2) Commercial facilities required for above commitments will be arranged for by this Headquarters. All other equipment will be furnished by the bases concerned.

(3) Frequencies for radio circuits will be listed in Appendix II, this Annex.

(4) Crypto and Authentication Systems will be as indicated in Appendix VIII, this Annex.

d. Tactical Units will:

(1) Crystallize aircraft in accordance with Appendix II, this Annex.

(2) Maintain aircraft radio equipment as required.

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Dir Comm

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RESTRICTED

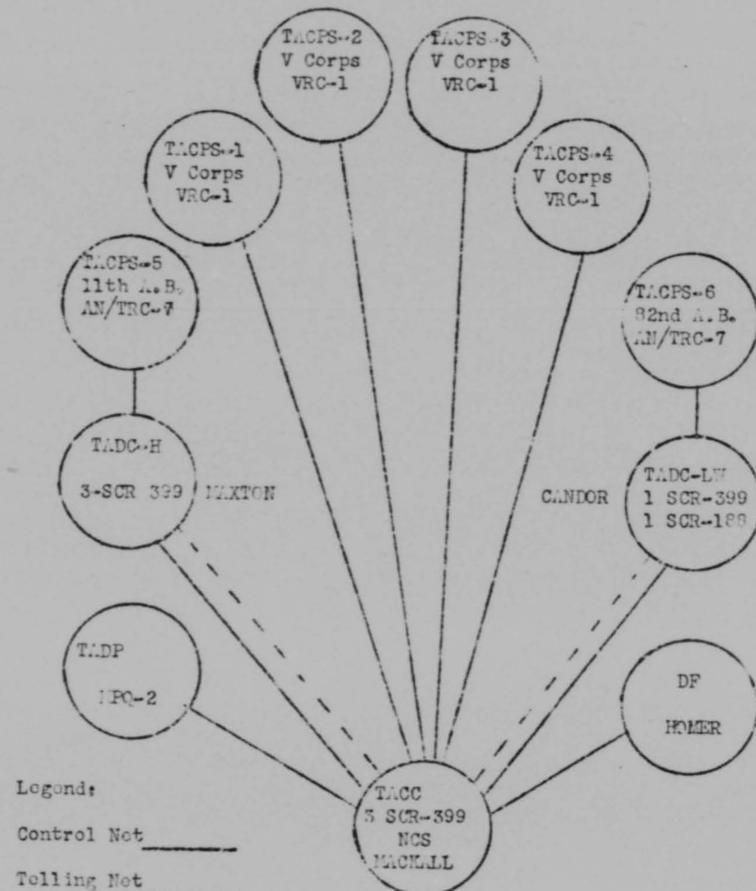
SECRET-SWARMER-SECRET

Operation Plan
TFAF No. 3-50

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

APPENDIX IV TO ANNEX F

CONTROL - TELLING NET HF



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SECRET - SWARMER - SECRET

0140

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SECRET-SWARMER-SECRET

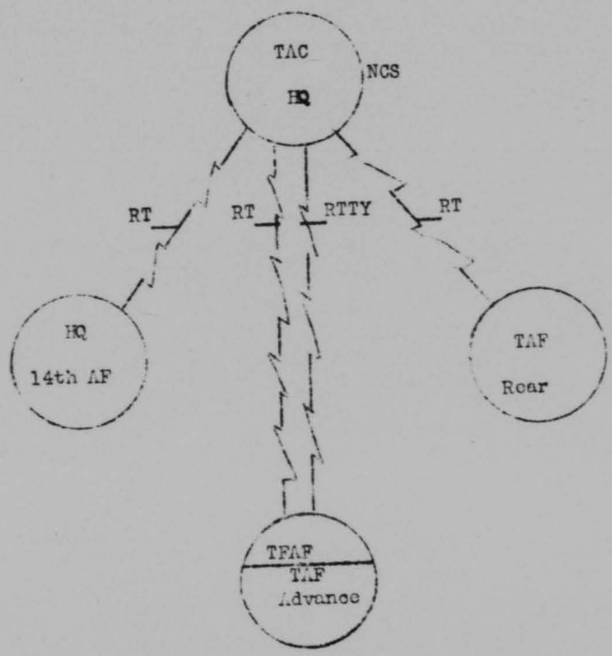
Operation Plan
TFAF No. 3-50

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

APPENDIX V TO ANNEX F

TACTICAL AIR COMMAND

COMMAND AND ADMINISTRATIVE NET



RESTRICTED

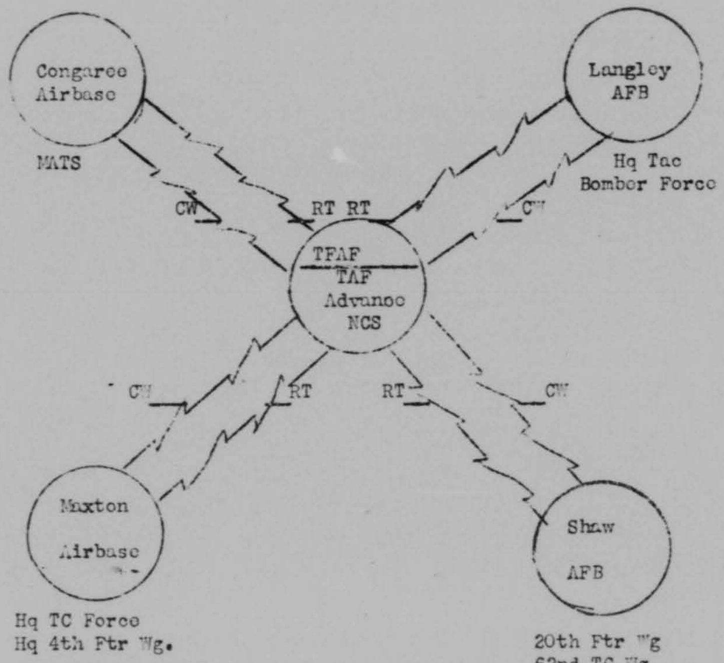
SECRET - SWARMER - SECRET

RESTRICTED

SECRET - SWARMER - SECRET

TACTICAL AIR FORCE

COMMAND AND ADMINISTRATIVE HF NET



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SECRET - SWARMER - SECRET

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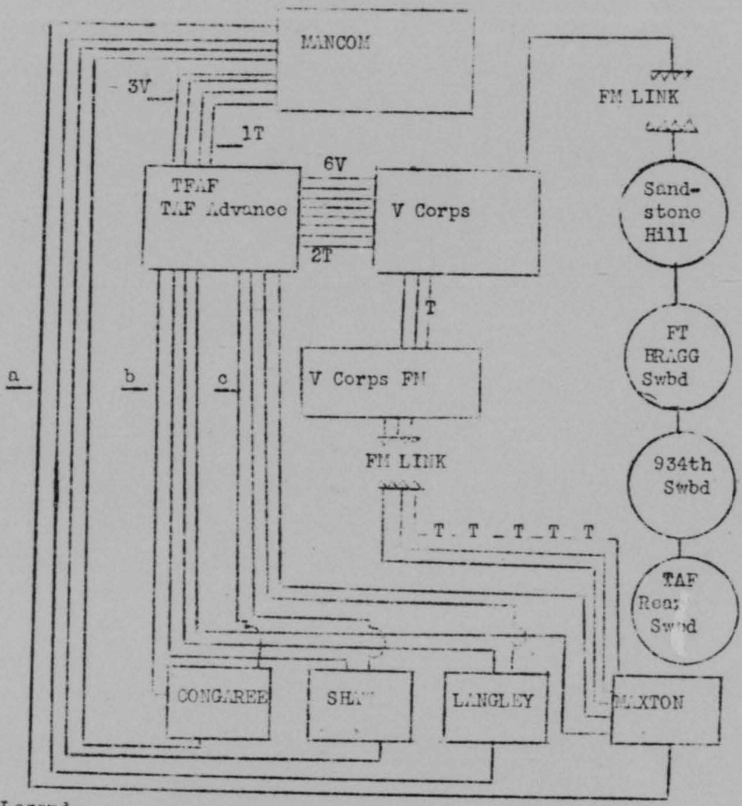
SECRET-SWARMER-SECRET

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX VI TO ANNEX F

TELEPHONE AND TELETYPE SYSTEM



Legend:

a Common User (Umpire)

b MANCOM Private Line (Terminates in Gp Opn's)

c TTY

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Lt. Col., USAF
Dir Comm

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SECRET - SWARMER - SECRET

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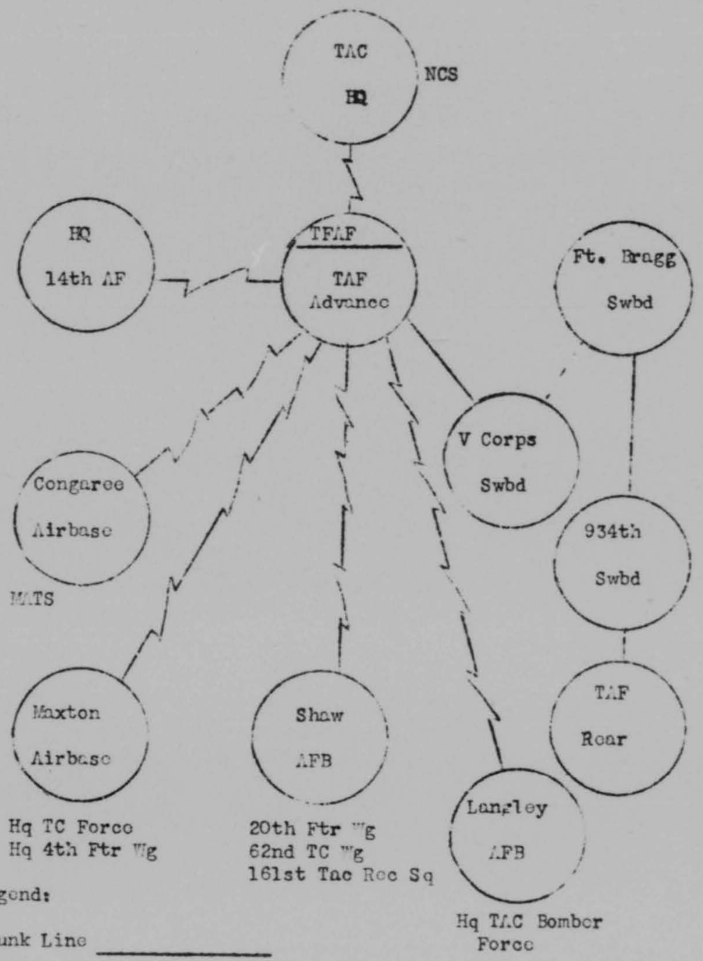
SECRET-SWARMER-SECRET

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX VII TO ANNEX F

COMMAND HF AND FM CIRCUIT USAGE



Legend:

Trunk Line ____________

HF Radio

FM Circuit - - - - - - - -

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SECRET - SWARMER - SECRET

0144

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SECRET-SWARMER-SECRET

Headquarter, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX X TO ANNEX F

TIME SIGNALS

1. Standard frequency transmissions are made continuously, day and night as a public service by the National Bureau of Standards over it's standard Frequency station, WWV, on the following frequencies:

MC	POWER (KW)
2.5	0.7
5.0	8.0
10.0	9.0
15.0	9.0
20.0	8.5

a. A .005-second pulse may be heard as a faint tick every second except the 59th second of each minute. These pulses may be used for accurate time signals. The audio frequencies are interrupted at precisely one minute before each hour and each five minutes thereafter (59th minute; 4 minutes past hour; 9 minutes past hour, etc.), resuming after an interval of precisely one minute. This one-minute interval is provided to give Eastern Standard Time (ZONE R) telegraphic code and to afford an interval in the checking of radio frequency measurements free from the presence of audio frequencies. The announcements of the stations services and call are given by voice at the hour and half hour. The time interval marked by the pulse every second is accurate to 0.000001 second. The beginning of the periods when the audio frequencies are resumed are synchronized with the basic time service of the U.S. Naval observatory.

2. The TACC will maintain a master time clock. Frequent time check will be made to insure the accuracy of this clock. TADC's and DF stations will obtain frequent time hacks from the TACC to insure all time hacks provided aircraft in flight are properly synchronized and accurate.

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SECRET - SWARMER - SECRET

0145

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SECRET-SWARMER-SECRET

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX XI TO ANNEX F

TIME ZONE AND TIME CONVERSION TABLES

TABLE OF TIME ZONES (WESTERN HEMISPHERE)

	Description	Suffix
0 to 7½W	0	Z
7½W to 22½W	+1	N
22½W to 37½W	+2	O
37½W to 52½W	+3	P
52½W to 67½W	+4	Q
67½W to 82½W	+5	R
82½W to 97½W	+6	S
97½W to 112½W	+7	T
112½W to 127½W	+8	U
127½W to 142½W	+9	V
142½W to 157½W	+10	W
157½W to 172½W	+11	X
172½W to 180	+12	Y

*GCT IS ZONE Z

TIME CONVERSION TABLE (U.S. AND MANEUVER AREA)

U(PST)	T(MST)	S(CST)	R(EST)	Q(E.R.)	P	Z(GCT)
1600	1700	1800	1900	2000	2100	0000
1700	1800	1900	2000	2100	2200	0100
1800	1900	2000	2100	2200	2300	0200
1900	2000	2100	2200	2300	0000	0300
2000	2100	2200	2300	0000	0100	0400
2100	2200	2300	0000	0100	0200	0500
2200	2300	0000	0100	0200	0300	0600
2300	0000	0100	0200	0300	0400	0700
0000	0100	0200	0300	0400	0500	0800
0100	0200	0300	0400	0500	0600	0900
0200	0300	0400	0500	0600	0700	1000
0300	0400	0500	0600	0700	0800	1100
0400	0500	0600	0700	0800	0900	1200
0500	0600	0700	0800	0900	1000	1300
0600	0700	0800	0900	1000	1100	1400
0700	0800	0900	1000	1100	1200	1500
0800	0900	1000	1100	1200	1300	1600
0900	1000	1100	1200	1300	1400	1700
1000	1100	1200	1300	1400	1500	1800
1100	1200	1300	1400	1500	1600	1900
1200	1300	1400	1500	1600	1700	2000
1300	1400	1500	1600	1700	1800	2100
1400	1500	1600	1700	1800	1900	2200
1500	1600	1700	1800	1900	2000	2300

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SECRET-SWARMER-SECRET

HEADQUARTERS
TASK FORCE AIR FORCE
EXERCISE SWARMER
POPE AIR FORCE BASE
FORT BRAGG, NORTH CAROLINA

OPERATION PLAN
TFAF 3-50

ANNEX G

METEOROLOGICAL PLAN

TABLE OF CONTENTS

RESTRICTED

SECRET-SWARMER-SECRET

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

ANNEX G

METEOROLOGICAL PLAN

1. General:

a. All units participating in exercise "SWARMER" operating from their home bases will be provided weather data and facilities by local weather detachments. Flight Service will provide any supplemental weather information necessary.

b. The 2060th Mobile Weather Squadron will establish detachments at CONGAREE, MANTON and MACKALL AIR BASES, and at the Joint Operations Center, Hq TAF. These detachments will provide twenty-four (24) hour observation and forecasting service as required.

2. Weather Observation:

a. Pilots will comply with existing Air Force policy in reporting "in-flight" weather phenomena as requested or in reporting any hazardous weather encountered. Proper voice radio procedure for this report will be as outlined in AN 08-15-1, (Radio Facility Chart), Page 153 Par D, "In Flight Weather Reports Sequence".

3. Dissemination:

a. TACC will be provided current weather data on an hourly basis, twenty-four (24) hours a day by the designated detachment.

b. In addition to maintaining current weather maps, special short and long range forecasts will be furnished the JOC as required.

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SECRET-SWARMER-SECRET

c. POPE AIR FORCE BASE weather detachment will provide ground to air weather information as required, either through the local AACS station or POPE AIR FORCE BASE tower.

Chester L. Sluder
CHESTER L. SLUDER
Colonel, USAF

HEADQUARTERS

TASK FORCE AIR FORCE

EXERCISE SWARMER

POPE AIR FORCE BASE

FORT BRAGG, NORTH CAROLINA

OPERATION PLAN
TFAF No. 3-50

ANNEX H

SPECIAL WEAPONS DEFENSE PLAN

(To be published at a later date)

HEADQUARTERS
TASK FORCE AIR FORCE
EXERCISE SWARMER
POPE AIR FORCE BASE
FORT BRAGG, NORTH CAROLINA

OPERATION PLAN
TFAF NO. 3-50

ANNEX I

ADMINISTRATIVE ANNEX

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Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N. C.
13 March 1950

Operation Plan
TFAF No. 3-50

ANNEX I

ADMINISTRATIVE ANNEX

1. GENERAL.

a. The Commanding Generals of parent Air Forces are responsible for providing logistical support to their units until such units arrive at the maneuver base.

b. All units will be inspected by Station Commanders at home station prior to departure to insure that units depart with equipment and supplies required for maneuver participation except as noted in Joint Support Agreements shown as Appendices to this Annex.

c. Property accountability and responsibility for supplies and equipment will be maintained throughout the field exercise in accordance with the provisions of AFM 67-1.

d. All requisitions submitted for equipment or supplies for the maneuver will contain a statement that items are required for Exercise SWARMER and Supply priority S-2 with Blue Streak action is authorized per ACMSA041-2-493-F.

e. Supply economy will be enforced at all echelons during the period of the maneuver.

f. Reports of survey for lost, damaged or destroyed TO&E property will be processed upon return of the unit to the home station.

g. Equipment on a loan basis from the maneuver bases that require survey action, will be placed on a report of survey prior to departure of the unit from the maneuver area. Units will not clear the maneuver area until all outstanding accounts have been settled.

2. Supply.

a. POPE AIR FORCE BASE.

(1) Supports Airdrome Control Unit and advance detachments of 314th Troop Carrier Wing and 4th Fighter Interceptor Wing at MAXTON AIR BASE for Class I and III from 15 March 1950 until opening of Carolina Base Section, CUTTER CAMP MACKALL.

(2) Continues to support elements of TFAF as are assigned maneuver sites within the POPE AFB area.

b. SHAW AIR FORCE BASE.

(1) Supports 20th Fighter Bomber Wing and USAF Tenant Units for all Class I, III, IV, and V supplies, and all services required beyond organizational abilities. Reference Appendix 3 to this Annex.

c. LANGLEY AIR FORCE BASE.

(1) Continues support of 84th and 85th Bomb Squadron during maneuver period.

d. MAXTON AIR BASE.

(1) Serves as Distribution Point for Classes I, III and IIIA to units based at MAXTON AIR BASE from 1 April to end of maneuver period.

e. CONGAREE AIR BASE.

(1) Serves as Distribution Point for Classes I, III and IIIA to units based at CONGAREE AIR BASE.

f. FOURTEENTH AIR FORCE

(1) Supports logistically Hq TFAF and all USAF units based in the maneuver area.

(2) Furnishes augmentation personnel for POPE AFB, MAXTON AIR BASE and CONGAREE AIR BASE.

(3) Furnishes supplies and equipment to units based at MAXTON AIR BASE, CONGAREE AIR BASE and POPE and SHAW AIR FORCE BASES, when such supplies and equipment are not available through T/O&E authorizations, but required for maneuver operations. (Reference Appendices 2, 3, and 4).

(4) Furnishes necessary fire and crash equipment and personnel required for airstrip operations within the CAMP MACKALL AREA.

(5) Furnishes necessary Air Combat Maneuver Funds required by USAF units participating in the Exercise, and for necessary repairs, utilities and rehabilitation at MAXTON and CONGAREE AIR BASES.

g. Army Installations.

(1) Carolina Base Section.

(a) SUPPLY POINT, OUTER MACKALL, opens 20 March, serves all USAF units based at MAXTON AIR BASE with Class I and III.

(b) Supply Point, FORT JACKSON, opens 20 March 1950, serves all USAF units at CONGAREE AIR BASE with Classes I and III.

(2) FORT BRAGG, NORTH CAROLINA.

(a) Cross-servicing agreement effective for support of POPE AFB and such minor units satallited thereon prior to opening of Carolina Base Section Supply Points.

h. Navy Installations.

(1) Naval units participating as USAF forces will operate from home stations, with logistical support through established naval channels.

i. Class I.

(1) MAXTON AIR BASE AREA.

(a) Airdrome Control Unit will consolidate requirements of USAF units and forward to Carolina Base Section, estimated three (3) days in advance.

(b) Supply Point distribution will be effected by Airdrome Control Unit from ration breakdown point established at MAXTON AIR BASE.

(c) Consolidated refrigerated facilities will be utilized at MAXTON AIR BASE Supply Point, with distribution direct to organizational messes.

(d) From 15 March until opening of Carolina Base Section Supply Point at CAMP MACKALL AREA, Airdrome Control Unit will submit requisitions to POPE AFB.

(2) SHAW AIR FORCE BASE.

(a) 20th Fighter Bomber Wing will provide Class I requirements to USAF Tenant Units.

(3) CONGAREE AIR BASE.

(a) USAF units will requisition on Supply Point, Carolina Base Section, FORT JACKSON. Supply Point distribution from consolidated requirement as determined by Airdrome Control Unit.

(4) LANGLEY AIR FORCE BASE.

(a) LANGLEY AFB will continue Class I support of 84th and 85th Bomb Squadrons.

j. Class II.

(1) MAXTON AIR BASE.

(a) USAF units will enter maneuver area with such individual and organizational equipment as required for the maneuver period, except as noted in Joint Use Agreement between 4th Fighter Wing, 314th Troop Carrier Wing, and 14th Air Force, attached as Appendix 2, 14th Air Force will furnish items in excess of T/O&E and T/A authorizations, and items specified in cited Joint Use Agreement, to avoid excess transportation costs.

(b) Thirty day level will be taken to maneuver area.

(c) All troop carrier and transport type aircraft will arrive at maneuver base with one parachute for each passenger seat, one loading ramp and one air cargo mooring kit per aircraft.

(2) SHAW AIR FORCE BASE.

(a) USAF Tenant Units will bring to SHAW AIR FORCE BASE all T/O&E and T/A equipment required to accomplish their assigned mission.

(b) Additional requirements will be furnished by SHAW AIR FORCE BASE and 14th Air Force. (Reference Appendix No. 3).

(c) Transport aircraft will arrive with one parchute for each passenger seat, one loading ramp and one air cargo mooring kit for each aircraft.

(3) CONGAREE AIR BASE.

(a) USAF units will arrive with necessary T/O&E and T/A equipment and supplies required to accomplish assigned mission.

(b) Additional requirements will be provided by 14th Air Force, (Reference Appendix No. 4).

(c) Transport aircraft will arrive with one parachute for each passenger seat, one loading ramp and one air cargo mooring kit for each aircraft.

(4) LANGLEY AIR FORCE BASE.

(a) Units based at LANGLEY AF BASE will furnish T/O&E and T/A equipment required to accomplish their assigned mission.

k. Class III.

(1) MAXTON AIR BASE.

(a) Airdrome Control Unit will submit consolidated vehicle gas and oil requirements for base units to Carolina Base Section, estimated three (3) days in advance.

(b) Supply point distribution OUTER CAMP MACKALL and MAXTON AIR BASE.

(2) SHAW AIR FORCE BASE.

(a) Requirements for base and tenant units will be procured through normal channels.

(3) CONGAREE AIR BASE.

(a) Motor gas and oil consolidated requirements for base units will be requisitioned by Airdrome Control Unit from Supply Point, Carolina Base Section, FORT JACKSON.

(4) LANGLEY AIR FORCE BASE.

(a) Requirements for units based at LANGLEY AFB will be processed through normal channels.

l. Class IIIA.

(1) Requirements for avgas and JP-1 fuel for all USAF units will be determined by Hq 14th AF and submitted to Hq ConAC.

(2) Hq ConAC, will effect necessary contractual arrangements to make available through local contractors the requirements of each maneuver base.

(3) Base supply officers will contact appropriate local contractors and arrange for scheduling of tank cars and/or trucks to appropriate maneuver bases.

(4) Hq. 14th AF will notify the foregoing officers of names and locations of avgas contractors.

(5) Similar procedures will be effected for procurement of necessary aircraft oils.

m. Class IV.

(1) USAF units will take the field with necessary Class IV supplies to include automotive spares to sustain their operation during the maneuver period.

(2) Expendable office supplies, cleaning materials, toilet paper, etc, will be provided from unit stocks and taken to maneuver area, except as indicated in Appendices 2, 3 and 4.

n. Class IVA.

(1) All participating units moving to maneuver bases will carry supplies sufficient to support their requirements during the maneuver period. Such supplies to include engines, oxygen, and normal maintenance spares.

o. Class V and VA.

(1) None required other than for security purposes; furnished by units.

(2) No live ammunition will be in the possession of individuals or units in the field excersise except that specifically authorized by the Commanding General, Task Force Air Force. Upon arrival in the maneuver area, each unit commander will certify in writing to the Commanding General, Task Force Air Force, that no live ammunition is on hand or in the possession of individuals of his unit.

p. Resupply.

(1) Resupply of Classes II and IIA and IV and IVA will be limited to emergency and AOCP requirements.

(2) Units based at MAXTON AIR BASE will effect resupply and AOCP procedures through home stations via assigned aircraft.

(3) SHAW AF BASE Supply will process AOCP requests for USAF Tenant Units.

(4) USAF units based at CONGAREE AIR BASE will process resupply and AOCP requirements through MATS channels.

(5) Units based at LANGLEY AF BASE will effect resupply through normal channels.

q. Salvage.

(1) Salvage generated at MAXTON AIR BASE will be turned into POPE AF BASE.

(2) Salvage generated at CONGAREE AIR BASE will be turned in to SHAW AF BASE.

(3) Salvage generated by base and tenant units at SHAW and LANGLEY AF BASE will be processed by station salvage officers.

3. Transportation.

a. Movement.

(1) Units moving to maneuver bases from home stations will move in accordance with movement plan shown in Appendix 1 to this Annex.

(2) Transportation officers at home stations of units concerned will be responsible for the movement of vehicles, via rail or convoy, from points of departure to destination, to include compliance with existing state laws and military regulations, and coordination with Commanding General of appropriate Army area concerned.

(3) Organizational aircraft will be utilized to the maximum.

(4) All movement will utilize the most economical mode of transportation possible.

(5) Loading and unloading of transport aircraft during the maneuver period to include necessary personnel and equipment, will be a responsibility of 7th Medium Port Units at maneuver bases.

4. Services.

a. Medical - Installations.

(1) MAXTON AIR BASE AREA.

(a) Unit-medical facilities will be supplemented by evacuation to, Field Hospital, V Corps, MAXTON AIR BASE for actual casualties.

(2) CONGAREE AIR BASE.

(a) Units medical facilities will be supported by Base Hospital, FORT JACKSON, SOUTH CAROLINA.

(3) SHAW AIR FORCE BASE.

(a) Base facilities will support all USAF units based at SHAW AFB.

(4) Actual deaths incurred during the Exercise will be evvacuated in accordance with Annex XV to General Plan, "SWARMER", dated 16 February 1950.

b. Medical - Health and Sanitation.

(1) Immunization will be current in accordance with existing regulations.

c. Maintenance.

(1) Current maintenance policies remain effective.

(2) Organization and field maintenance will be performed by all units to the maximum extent consistant with availability of equipment and skill of personnel.

(3) Aircraft, vehicles and other equipment requiring repair beyond the capabilities of organizations will be reported to 14th AF.

d. Construction and Repair.

(1) Anticipated and minimum requirements for repair construction and rehabilitation of facilities at MAXTON and CONGAREE AIR BASES will be performed by Airdrome Control Units except renovation of fuel storage system at MAXTON AIR BASE.

which will be performed by the 14th AF.

e. Laundry.

(1) USAF units based at MAXTON AIR BASE and POPE AFB will utilize the facilities of the Post QM Laundry, FORT BRAGG, in accordance with schedules arranged by the Airdrome Control Unit MAXTON AIR BASE, and the Supply Officer POPE AFB, respectively.

(2) USAF units based at CONGAREE AIR BASE will provide laundry service by local contract.

(3) USAF Units based at SHAW AND LANGLEY AFB will utilize existing base facilities.

f. Post Exchange.

(1) MAXTON AIR BASE AREA will be serviced by branch post exchange operated by FORT BRAGG.

(2) USAF Units in CONGAREE AIR BASE will be serviced by branch exchanges from FORT JACKSON, SOUTH CAROLINA.

(3) USAF Units at POPE, LANGLEY and SHAW AFBBASES will utilize current facilities.

g. Funds.

(1) Requirements for air combat maneuver funds will be computed by all USAF participating units and furnished to Hq, 14th AF by 15 March 1950.

(2) Allocation of fund requirements will be effected by Hq, 14th AF for expenditures directly required for participation in Exercise SWARMER.

5. Personnel.

a. Troop Strength Reports and Records.

(1) Strength of units will be as authorized in T/O&E applicable to individual unit.

(2) Reports. All Air Force units who move their administrative headquarters to operations area of SWARMER will prepare and forward morning reports and other required personnel reports to the Commanding General of the respective Air Force headquarters to which they are assigned, attention: Director of Statistical Services. Other units of the Air Force who have personnel on duty with subject operations will make appropriate remarks daily in the remarks section of their morning report and indicate the total number of officers and airmen who are on TDY with Exercise SWARMER. Detachments participating in subject exercise will not prepare detachment reports except as may be required by their parent unit. It will be the responsibility of the parent Air Force units to forward all instructions and directives to organizations concerned for preparing personnel reports.

(3) Records. Essential records and allied papers will accompany units while in maneuver area.

b. Replacements.

(1) Current policies will govern. Actual replacements will not join units after their departure from home station until their return thereto.

c. Personnel Procedures.

(1) Leaves and passes. Personnel participating in the exercise will not be granted leave, except for emergency reasons. Passes may be granted at the discretion of unit commanders if off duty time permits. Uniform while on pass will be class "A" Summer.

d. Morale.

(1) Pay of Airmen. All units ordered to maneuver area will be paid by the finance officer regularly paying the unit at home station. Unit Commanders will appoint Class "A" Finance Agent who will arrange with home station finance officer to make payment of airmen and officers in the maneuver area at the regular pay roll date.

(2) Payment for rations issued in kind. All Airmen authorized to ration separately will be removed from such status by appropriate Commander prior to departure from home station. They will not again be authorized separate rations until they return to home station. Officers eating at troop messes will pay cash for all meals to the mess officer of the mess in which meals are consumed.

(3) Personal affairs. No dependents will accompany sponsors to maneuver area. All Commanders will instruct officers and airmen prior to departure to arrange their personal affairs to insure that a minimum of headship is caused dependents by the absence of heads of families during the maneuver period.

(4) Special Services. Every effort will be made to furnish entertainment to airmen during pre-and post maneuver periods by Air Force Base Commanders.

(a) All units will bring the minimum essential athletic equipment from home station.

(5) Postal Service. Mail will be handled, insofar as practicable, in accordance with procedures for a theater of operations, (Reference Chapter 5, TM 12-205.)

(a) All mail, official and personal, addressed to organization or Air Force personnel on the maneuvers, except as noted in (b) below, will be addressed with name, grade, service number, number of Squadron, Group, Wing or next higher element to which the unit is assigned or attached and addressed to the Maneuver Base to which the unit is ordered from home station.

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EXAMPLE: Pvt Joh Jones, 32 000 000
60th TC Sq, 385 TC Wing
Shaw AFB, S.C.

(b) All mail addressed to observers, will be plainly marked "Observer" followe d by "Visitors Bureau", Exercise Exercise Swarmer, Fort Bragg, N. C.

EXAMPLE: Capt John Smith AO 275 000
Observer - Vistor's Bureau
Exercise Swarmer
Fort Bragg, N.C.

e. Civilian Personnel: will not participate in this Exercise.

f. Law and Order.

(1) The Provost Marshal, FORT BRAGG, N. C. is responsible for coordination with Hq. V Corps, Hqs TFAF and North Carolina State Police with reference to military police functions and responsibilities in the FORT BRAGG, CAMP MACKALL - LAURINBURG-MAXTON AREA. The Provost Marshal, FORT JACKSON, S. C. will effect similiar coordination for South Carolina.

(2) The Commanding General, V.Corps and Commander Carolina Base Section, is responsi ble for law and order and traffic control in the sectors of the maneuver area under their control.

(3) Commanding General, TFAF, is responsible for traffic control and maintenance of law and order in his sector of operations.

(4) Troops will be contained within the sector of operations. Collection points will be operated to serve as control points for apprehension of absentees and stragglers. (See para, g, below).

(5) Courts Martial Jurisdiction. For the purpose of the exercise, all personnel assigned to Air Force units will come under the Commanding General, 14th Air Force for General Court Martial jurisdiction and Article of War 104 jurisdiction when appropriate. Attachment of individuals or units for administration includes attachment for Courts-Martial Jurisdiction.

(6) Claims. The responsibility for designation of claims officers to investigate accidents or incidents which might result in claims by or against the Government rests with the Commanding Officer of Groups or commensurate units. (Ref AFR 112 series).

g. Prisoners of War.

(1) Facilities needed for handling prisoners of war is the responsibility of the Commanding General, V Corps and Commanding General, TFAF.

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(2) Captured personnel will not be held longer than 48 hours for interrogation. Chief Umpire is responsible for daily exchange of Prisoners of US and Aggressor Forces.

h. Miscellaneous Personnel Activities.

(1) Public Information activities will be as prescribed by the Commanding General TFAF.

(2) Identification tags will be worn by all personnel participating in the Exercise.

6. Miscellaneous.

a. Location of Headquarters.

(1) Hq. TASK FORCE SWARMER, FORT BRAGG, NORTH CAROLINA.

(2) Hq. TFAF, OUTER CAMP MACKALL, NORTH CAROLINA.

(3) Hq. V Corps OUTER CAMP MACKALL, NORTH CAROLINA.

(4) Hq. 14th Air Force, ROBINS AIR FORCE BASE, GEORGIA.

(5) Hq. 9th Air Force, LANGLEY AIR FORCE BASE, VIRGINIA.

(6) Hq. Carolina Base Section, OUTER CAMP MACKALL, N. C.

b. Special Reports.

(1) Unit Commanders will submit the following reports to commander of installations to which units are assigned for maneuver participation, forty-eight (48 hours prior to departure of personnel from home station. Report will apply to all movements shown in Appendix 3 and will include.

(a) Departure date.

(b) ETA.

(c) Troop Strength (roster of troops).

c. Administration.

(1) Uniform for maneuver period will be Summer.

CHESTER L. SLUDER
Colonel, USAF

Appendices:

I - Movement Plan.
II - Support Agreement, MAXTON AIR BASE, N. C.
III - Support Agreement, SHAW AIR FORCE BASE, S.C.
IV - Support Agreement, CONGAREE AIR BASE, S. C.
V - Uniform and Equipment.

RESTRICTED

SECRET-SWARMER-SECRET

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N. C.
13 March 1950

Operation Plan
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APPENDIX I TO ANNEX I

MOVEMENT PLANS

1. GENERAL. Air Force organizations will move from home stations to the maneuver area as prescribed below. Redeployment from maneuver area to home stations will be as prescribed by the TFAF at a later date. Maneuver Base Commanders will be notified by the Unit Commanding Officers seven (7) days in advance of the arrival of personnel, giving strength of officers and airmen for necessary arrangements for rations.

2. 314th Troop Carrier Wing.

a. Scheduling.

(1) Personnel and equipment for the Airdrome Control Unit will arrive at MAXTON AIR BASE in sufficient time to be operational by 15 March 1950.

(2) The advance party will arrive at MAXTON AIR BASE not later than 1 April 1950.

(3) The Main Body will arrive at MAXTON AIR BASE not later than 13 April 1950 and the entire Wing at MAXTON AIR BASE will be in operational readiness by 15 April 1950.

b. Type of Movement.

(1) The Airdrome Control Unit will move by motor convoy with heavy equipment to be shipped by rail.

(2) The Advance Party will move by assigned aircraft and motor convoy.

(3) The Main Party will move by assigned aircraft and motor convoy.

3. 4th Fighter-Interceptor Wing.

a. Scheduling.

(1) Personnel and equipment for the Airdrome Control Unit will arrive at MAXTON AIR BASE in sufficient time to be operational by 15 March 1950.

(2) The Advance Party will arrive at MAXTON AIR BASE not later than 1 April 1950.

(3) The Main Body will arrive at MAXTON AIR BASE to be operational by 15 April 1950.

RESTRICTED

SECRET-SWARMER-SECRET

b. Type of Movement.

(1) All personnel and equipment will move by aircraft under the control of the Commanding General, 9th Air Force.

4. 7th Troop Carrier Squadron.

a. Scheduling.

(1) The Advance Liaison Detachment will arrive at the maneuver base not later than 1 April 1950.

(2) The Main Body will arrive at the maneuver base not later than 15 April 1950 and the squadron operational by 15 April 1950.

b. Type of Movement.

(1) All personnel and equipment will move by assigned aircraft.

5. 84th and 85th Bomb Squadrons.

a. Will operate from home station, LANGLEY AFB, with no movement involved.

6. 20th Fighter Bomber Wing.

a. Will operate from home station, SHAW AFB, with no movement involved.

7. 161st Tactical Reconnaissance Squadron.

a. Will operate from home station, SHAW AFB, with no movement involved.

8. 502nd Tactical Control Group.

a. Will operate in the Maneuver Area as directed by TFAF. Assigned vehicles will be used for all movement.

9. 934th Signal Battalion.

a. Will operate in the Maneuver Area as directed by TFAF. Assigned vehicles will be used for all movement.

10. 1st Shoran Beacon Unit.

a. Will operate in the Maneuver Area as directed by TFAF. Assigned vehicles will be used for all movement.

11. 4th Liaison Flight.

a. Will operate in the Maneuver Area as directed by TFAF.

12. Troop Carrier Units (Reserve).

a. Scheduling.

(1) Advance liaison detachments (ref appendix 3) will arrive SHAW AFB not later than 15 April 1950.

(2) Remaining units will arrive SHAW AFB not later than 27 April and be operational by 29 April 1950.

b. Type of Movement.

(1) Personnel and equipment will move via assigned aircraft.

13. MATS.

a. Scheduling.

(1) Will arrive at CONGAREE AIR BASE in sufficient time to be in operational readiness by 15 April 1950.

b. Type of Movement.

(1) Personnel and equipment will move via assigned aircraft.

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Colonel, USAF

Authenticated:

ROBERT MORRIS
Colonel, USAF
Deputy for Materiel

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N. C.
13 March 1950

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APPENDIX II TO ANNEX I

SUPPORT AGREEMENT - MAXTON AIR BASE

1. GENERAL. This appendix delineates mutual support agreed upon by and between Commanding General, 14th Air Force, Commanding General 314th Troop Carrier Wing, and Commanding General, 4th Fighter Interceptor Wing, for joint tenancy for MAXTON AIR BASE during the period 1 April 1950 to 15 May 1950 for participation in Exercise SWARMER.

2. Administration.

a. The Commanding General, 314th Troop Carrier Wing will have command responsibility of common administrative and logistic functions of the Air Base.

(1) To perform these functions, there will be established an Airdrome Control Unit to be manned and equipped by Commanding General, 314th Troop Carrier Wing augmented by the Commanding General, 4th Fighter-Inteceptor Wing as mutually agreed upon between the two commanders concerned.

(2) Administrative and Logistic responsibilities of the Airdrome Control Unit will include the following:

(a) Administrative operation of base headquarters.

(b) Base Operations and fire and crash protection.

(c) Repairs and utilities functions.

(d) Class I supply point distribution. Consolidation of requirements and submission to Carolina Base Section.

(e) Class III and IIIA procurement, storage and issue. Coordination with contractor and Carolina Base Section for delivery of fuel to MAXTON AIR BASE.

(f) Internal security.

3. Activation of MAXTON AIR BASE

a. The Commanding General, V Corps will acquire use of the MAXTON AIR BASE and certain facilities thereat for use of USAF Units during the period 13 March 1950 to 15 May 1950.

b. The Airdrome Control Unit will prepare air field for occupancy by accomplishing the following prior to 1 April 1950.

(1) Appoint a responsible officer who will establish an M/R Account with POPE AFB for those items furnished by Headquarters, 14th Air Force and FORT BRAGG.

(2) Renovation of water and sewage systems.

(3) Renovation of electrical system.

(4) Arranging with local Utilities Companies for service during period of Exercise.

(5) Erection of washing, bathing and latrine facilities.

(6) Repairs to buildings, grounds, roads, runways and parking aprons as approved by Headquarters, 14th Air Force.

(7) Installation of field lighting system.

(8) Clearing bivouac areas.

(9) Cutting grass on airdrome.

(10) Repairing wind direction indicator.

c. The Commanding General, 14th Air Force will support the Commanding General, 314th Troop Carrier Wing, Commanding General, 4th Fighter Interceptor Wing, and Commanding Officer, Airdrome Control Unit, as follows:

(1) Arrange for renovation of fuel storage systems by Contract, Ready date - 1 April 1950.

(2) Arrange with Carolina Base Section, FORT BRAGG, and POPE AFB for local support of USAF Units during period of Exercise. Local support will consist of the following.

(a) Class I supplies.

(b) Class III supplies.

(c) Exchange, laundry and theater services.

(3) Submit Class IIIA requirements to highter headquarters and arrange for tank car delivery to MAXTON AIR BASE as required.

(4) Furnish 4th Fighter Interceptor Wing general and special purpose vehicles required to accomplish their assigned mission. This does not include vehicles, equipment, ground handling equipment and tools peculiar to assigned aircraft.

(5) Furnish Commanding Officer, Airdrome Control Unit, general and special purpose vehicles, equipment, tools and personnel beyond the capabilities of the Commanding General, 314th Troop Carrier Wing, and Commanding General, 4th Fighter Interceptor Wing.

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4. Operations.

a. The 314th Troop Carrier Wing, 4th Fighter Interceptor Wing and Airdrome Control Unit will be under Operational Control of TFAF while based at MAXTON AIR BASE.

CHESTER L. SLUDER
Colonel, USAF

Authenticated:

Robert Morris
ROBERT MORRIS
Colonel, USAF
Deputy for Materiel

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Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N. C.
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX III TO ANNEX I

SUPPORT AGREEMENT - SHAW AIR FORCE BASE

1. GENERAL. This appendix delineates the support agreed upon by the Commanding General, 14th Air Force and the Commanding General, 20th Fighter Bomber Wing, to be furnished USAF Tenant Units at SHAW AFB during Exercise SWARMER.

2. Administrative and Logistical Support.

a. Facilities.

(1) Billeting and Messing.

(a) 20th Fighter Bomber Wing will furnish barracks, cots, bedding, kitchen and mess equipment, etc., for housing and messing for 100 officers and 150 airmen of the USAF Tenant Units.

(2) Administrative and Operational Office Space.

(a) 20th Fighter Bomber Wing will furnish required administrative office space, operation briefing rooms, etc., to USAF Tenant Units in locations mutually agreed upon.

(3) Communications.

(a) 20th Fighter Bomber Wing will provide necessary telephones, point to point radio, crytographic equipment required for operating personnel of the USAF Tenant Units.

(4) Refueling and Crash Fire Requirements.

(a) To be furnished by 20th Fighter Bomber Wing, with augmentation personnel from USAF Tenant Units if required.

(5) Maintenance Shops, Working and Parking Areas.

(a) 20th Fighter Bomber Wing will furnish parking space for a maximum of thirty-six cargo type aircraft, and the use of such common shop facilities and equipment as may be used by personnel of USAF Tenant Units for repair of unit aircraft. No covered maintenance area will be available.

b. Funds.

(1) 14th Air Force will provide ACW funds to SHAW AFB for requirements generated by USAF Tenant Units during the maneuver period.

(2) Local procurement of items peculiar to Exercise SWARMER will be charged to ACW Funds.

c. Supply.

(1) Class I - Furnished by 20th Fighter Bomber Wing.

(2) Class II and IIA.

(a) USAF Tenant Units will bring to SHAW AFB such items of T/O&E, T/A and individual equipment required for performance of their maneuver mission.

(b) 14th Air Force will provide such equipment, special purpose vehicles and ground handling equipment required but impracticable for air shipment from home station and not available from 20th Fighter Bomber Wing.

(3) Class III and IIIA.

(a) Avgas, JP-1 and aviation oils will be made available at SHAW AFB for all USAF Units as prescribed in paragraph 2 Annex I.

(b) Motor vehicle gasoline and oils will be procured by 20th Fighter Bomber Wing from normal sources for USAF Tenant Units on a reimburseable basis from ACM Funds.

(4) Class IV and IVA.

(a) USAF Tenant Units will bring supplies sufficient to support assigned aircraft during the maneuver period.

(b) Emergency resupply and AOCP items will be effected by 20th Fighter Bomber Wing.

d. Transportation and Services.

(1) Vehicle transportation required by USAF Tenant Units for transporting personnel to and from working and billeting areas will be furnished by 20th Fighter Bomber Wing.

(2) Normal base services, including medical, laundry, post exchange, theaters, etc., will be furnished to the USAF Tenant Units by the 20th Fighter Bomber Wing.

3. Operations.

a. USAF Tenant Units will be under the operational control of Troop Carrier Force while on tenant status.

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4. Miscellaneous.

a. USAF Tenant Units will provide a liaison supply officer to 20th Fighter Bomber Wing by 15 April 1950, to act as responsible officer for use of non-expendable equipment and supplies furnished by 20th Fighter Bomber Wing.

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ROBERT MORRIS
Colonel, USAF
Deputy for Materiel

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N. C.
13 March 1950

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APPENDIX IV TO ANNEX I

SUPPORT AGREEMENT - CONGAREE AIR BASE

1. GENERAL. This appendix delineates the mutual support agreed upon by the Commanding General, MATS, Commanding General 62nd Troop Carrier Wing and the Commanding General, 14th Air Force for the use of CONGAREE AIR BASE during Exercise SWARMER.

2. Administration. The 14th Air Force will make the necessary arrangements with Adjutant General, South Carolina for the use of CONGAREE AIR BASE and certain facilities thereat as listed in paragraph 3.

3. Facilities.

a. Billeting and messing.

(1) Barracks and mess installations are available for approximately 2000 men.

(2) No bedding or mess equipment available.

b. Administrative and Operational Buildings.

(1) Sufficient covered space is available for administrative requirements, and for base operations, briefing, etc.

(2) No hangar space is available for maintenance work.

(3) Covered storage is available for base supply activities.

c. Gasoline Storage.

(1) Operational 100,000 gal avgas storage is available, less normal operational requirements of ANG.

(2) 25,000 gal motor vehicle gas storage is available.

d. General and special purpose vehicles:

(1) Crash and Structural Fire Fighting.

(a) 1-125 - Crash Trucks.

1-135 - Crash Trucks.

1- Ambulance.

(2) No refueling units can be furnished by ANG.

(3) No general or special purpose vehicles or ground handling equipment of any kind can be furnished by the ANG.

(4) Building No. 72, roof and concrete floor only, may be utilized for motor pool activities.

e. Utilities.

(1) Water, sewage and electricity will be available.

4. USAF Units will be responsible for provision of:

a. All aircraft crews and supporting maintenance and supply personnel.

b. Organizational equipment required to support the C-54 aircraft during the maneuver period to include:

(1) 20 day level of class IVA supplies peculiar to C-54 aircraft.

(2) Necessary administrative personnel for performing the operational mission.

c. Individual equipment, to include mess kits, clothing, and toilet articles.

5. The 14th Air Force will support the operational functions of USAF Units by providing normal base housekeeping functions.

a. To perform these functions, the 14th Air Force will establish an Airdrome Control Unit, which will be responsible for:

(1) Administrative operations of base headquarters.

(2) Operating messing facilities for USAF Units.

(3) Renovation, Repairs and Utilities functions.

(4) Maintaining and operating general and special purpose vehicles required.

(5) Medical, laundry, and exchange services.

(6) Internal Security of Air Base.

(7) Necessary transient services.

(8) Provision of billets for USAF personnel to include cots and blankets only.

(9) Class I.

(a) Effecting necessary arrangements with Supply Point, Carolina Base Section, FORT JACKSON, for daily requirements.

(b) Operating ration breakdown point at CONGAREE AIR BASE.

(10) Class III.

(a) Arranging with supply point Carolina Base Section, FORT JACKSON for daily requirements.

(b) Operating storage and distribution point at CONGAREE AIR BASE.

(11) Class IIIA.

(a) Arranging with designated contractor for delivery of daily avgas requirements.

(b) Operating avgas storage and issue point.

(c) Operating aircraft refueling units to provide necessary service to USAF Units and transient aircraft.

(12) Operations of crash and fire equipment.

b. To support the Airdrome Control Unit, the 14th Air Force will provide all personnel, supplies, equipment, vehicles, and fuel required.

c. The 14th Air Force will arrange with SHAW AFB for the following:

(1) Purchasing and Contracting Services required at CONGAREE AIR BASE.

(2) Provisions from base stocks or by requisition, supplies and equipment designated by 14th Air Force for support of CONGAREE AIR BASE.

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Deputy for Materiel

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N. C.
13 March 1950

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APPENDIX V TO ANNEX I

UNIFORM AND EQUIPMENT

1. The following items of individual and organizational clothing and equipment will be required for personnel participating in Exercise SWARMER.

2. Items marked with an asterisk are additional items required by personnel moving into the air head.

Individual Clothing and Equipment	Allowance	Remarks
Belt, Waist, Web	2 ea	Per AM, Off
Shoe, Service	2 Pr	"
Shoe, Low Quarter	1 Pr	"
Cap, Garrison, Khaki	1 Pr	"
Drawers, Cotton, Shorts	5 Pr	"
Insignia	As Prescribed	
Necktie, Cotton, Mohair	2 ea	"
Shirt, Cotton, Khaki	5 ea	"
Shirt, Poplin Khaki	2 ea	"
Socks, Cotton, Tan	5 ea	"
Socks, Wool, Cushion Sole	2 ea	"
Trousers, Cotton, Khaki	5 pr	"
Undershirt, Cotton, Quarter-sleeve	5 ea	"
Bag, Duffel	1 ea	"
Necklace, Identification tag w/extension	1 ea	"
Tag, Identification	2 ea	"
Towel, bath	2 ea	"
Comb	1 ea	"
Handkerchiefs	5 ea	"
Razor	1 ea	"
Soap, Shaving	1 ea	"
Tooth brush	1 ea	"
Tooth Paste or Powder	1 ea	"

Organizational Clothing and Equipment	Allowance	Remarks
Cap, Herringbone Twill	2 ea	Per AM
Hood, Jacket	1 ea	Optional
Jacket, Field M-43	1 ea	Per AM, Off
Suit, Working, One-piece, HT-OD	3 ea	Per AM
Poncho, Lightweight, OD	1 ea	Per AM, Off
or		
Raincoat, Rubberized, M-38 Dismounted	1 ea	"
Belt, Pistol, or revolver M-36	1 ea	Per Ind armed w/-pistol or carbine
Helmet, Steel M-1	1 ea	Per AM, Off
Band, Liner, Helmet, M-1, Neck	1 ea	"

Operation Plan
TFAF No. 3-50

Organizational Clothing and Equipment	Allowance	Remarks
Band, Liner, Helmet, M-1, Head	1 ea	Per AM, Off
Liner, Helmet, M-1	1 ea	"
Packet, First Aid	1 ea	"
Pocket, Cartridge, Cal, 30 M-1 Carbine	1 ea	Per AM w/ carbine
Pocket, Magazine, double, Web	1 ea	Per Ind with pistol
Pouch, First Aid Packet	1 ea	Per AM, Off
Canteen, M-10	1 ea	1 ea
Cover, Canteen, M-10	1 ea	1 ea
Cup, Canteen	1 ea	1 ea

Individual Clothing and Equipment	AIRMEN	OFFICERS
Bag, Sleeping (as auth.)		1 ea
*Bag, canvas, field M-36 or equal	1 ea	1 ea
Blanket, Wool OD	2 ea	2 ea
Can, Meat	1 ea	1 ea
*Carrier, axe, entrenching	1 ea per axe entrenching	
*Carrier, pick, mattock	1 ea per pick mattock tool	
*Carrier, shovel, entrenching	1 ea per shovel entrenching	
Fork, M-26	1 ea	1 ea
*Entrenching tool, axe	1 ea per 10 AM	
*Entrenching tool, pick mattock	1 ea per 10 AM	
*Entrenching tool, shovel	7 ea per 10 AM	
Knife, M-26	1 ea	1 ea
*Pin, tent	5 ea	10 ea
*Pole, tent	1 ea	2 ea
*Shelter, half	1 ea	2 ea
Spoon, M-26	1 ea	1 ea
*Strap, carrying bag field	1 ea	1 ea
*Suspenders, belt, M-36	1 ea	1 ea w/bag canvas field M-36
Arms and ammunition	as prescribed	
Flash lights, SCR-122	1 ea (1st Three Grader)	1 ea

CHESTER L. SLUDER
Colonel, USAF

Authenicated:

ROBERT MORRIS
Colonel, USAF
Deputy for Materiel

HEADQUARTERS

TASK FORCE AIR FORCE

EXERCISE SWARMER

POPE AIR FORCE BASE

FORT BRAGG, NORTH CAROLINA

OPERATION PLAN
TFAF No. 3-50

ANNEX J

PUBLIC INFORMATION

(To be published at a later date)

HEADQUARTERS
TASK FORCE AIR FORCE
EXERCISE SWARMER
POPE AIR FORCE BASE
FORT BRAGG, NORTH CAROLINA

OPERATION PLAN
TFAF No. 3-50

ANNEX K

REPORTS

TABLE OF CONTENTS

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RESTRICTED

SECRET-SWARMER-SECRET

Operation Plan
TFAF No. 3-50

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N. C.
13 March 1950

ANNEX K

REPORTS

1. General: Routine reports will be submitted as outlined in Appendices I through III, this Annex.

2. Intelligence Reports: Intelligence reports will be submitted as outlined in Appendix I to Annex C.

3. Historical Reports: Historical reports will be submitted as outlined in Appendix VI to Annex C.

Chester L. Sluder
CHESTER L. SLUDER
Colonel, USAF

Appendices:

I JOC Reports

II Materiel & Equipment Report

III Special Weapons Report

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SECRET-SWARMER-SECRET

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX I TO ANNEX K

JOC REPORTS

1. Daily: Daily reports of flying and ground training activities will be submitted by TWX to Joint Operations Center by 1000 hours giving information oulined in TAB A (JOC Forms #1 and #2).

2. Weekly: Weekly consolidated reports of flying and ground training activities will be submitted by TWX to the JOC by 1200 hours, Monday of each week as outlined in TAB A (JOC Forms #1 and #2).

3. Telephone Status Reports: All Tactical Units under control of Headquarters, Task Force Air Force, will render reports to JOC as indicated:

a. TAB B (JOC Form #3). This report will be submitted by telephone prior to daylight daily. Changes in status during the day will be submitted immediately.

b. TAB B (JOC Form #4). This information will be submitted to the JOC by 1530 daily.

c. TAB C (JOC Form #5). This report will be submitted to the JOC after take-off of each aircraft or group of aircraft.

d. TAB C (JOC Form #6). This report will be submitted immediately upon landing of any aircraft or group of aircraft.

4. Accident Report: All accident reports will be submitted in accordance with AFR 62-14, as amended. Information copies of preliminary and final reports will be forwarded to Headquarters, Tactical Air Force. (Prov).

3 TABS:

A -- JOC Forms 1 2

B -- JOC Forms 3&4

C — JOC Forms 5&6

CHESTER L. SLUDER
Colonel, USAF

Authenticated:

William F. Mandt

WILLIAM F. MANDT
Lt. Colonel, USAF
Dep. for Opns.

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JOC Form #1 and #2

ACTIVITY REPORT: ______________________
(Organization)

1. Period covered by report ______________________

2. Total flying hours ______________________

3. Breakdown of sorties by type:

Fighter

a. Fighter Sweeps ______
b. Fighter Escort ______
c. Flak Suppres. ______
d. GCI ______
e. Rocket ______
f. Bomb ______
g. Air Defense ______
h. Test Flights ______
i. Miscellaneous ______

Reconnaissance

a. Vertical Photo ______
b. Oblique Photo ______
c. Visual Recon ______
d. Route Recon ______
e. Artillery Adj ______
f. Omitted ______
g. Omitted ______
h. Test Flights ______
i. Miscellaneous ______

Troop Carrier

a. Para-drop ______
b. Aerial resupply ______
c. Airlanded resupply ______
d. Airlanded troops ______
e. Glider Tow ______
f. Glider pick-up ______
g. **Pathfinder** ______
h. Test Flights ______
i. Miscellaneous ______

Bomber

a. High level bombing ______
b. Low level bombing ______
c. Shoran bombing ______
d. Cruise Control ______
e. Omitted ______
f. Omitted ______
g. Omitted ______
h. Test Flights ______
i. Miscellaneous ______

Note: Dual type missions will be reported under one type only.

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SECRET-SWARMER-SECRET

DATE

JOC F6rm # 3

JOC Form # 4

UNIT	TYPE ACFT	IN	OUT	OUT AOCP	TIME	UNIT	EST.NO.ACFT FOR FOLLOWING DAY	TIME

TAB B

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SECRET-SWARMER-SECRET

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DATE

JOC Form # 5 JOC Form # 6

UNIT	MISSION NO. & MISSION	FLIGHT CALL WORD	NO. ACFT	TIME OFF	TIME DOWN	NO. & STAT. OF ACFT NOT LAND	SUCCESS OF MSN

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SECRET-SWARMER-SECRET

Operation Plan
TFAF No. 3-50

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N. C.
13 March 1950

APPENDIX II TO ANNEX K

MATERIEL AND EQUIPMENT REPORT

1. A daily report (TFAF Report DM-1) will be submitted by electrical means to Headquarters, Task Force Air Force, by 1000 hours daily as of 2400 hours for the preceeding day. Attached as TAB "A" is the outline form to be used. This report is to begin 15 April 1950 and end the last day of the maneuver.

1 Tab :

A -- D/M Form 1

CHESTER L. SLUDER
Colonel, USAF

Authenticated:

William F. Mandt
WILLIAM F. MANDT
Lt. Colonel, USAF
Dep. for Opns.

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SECRET - SWARMER - SECRET

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SECRET-SWARMER-SECRET

Headquarters, Task Force Air Force
Exercise SWARMER
POPE AIR FORCE BASE, FORT BRAGG, N.C.
13 March 1950

Operation Plan
TFAF No. 3-50

APPENDIX III TO ANNEX K

SPECIAL WEAPONS REPORT

1. Immediate Flash Reports:

a. Submitted by most expeditious means availabe by all organizations immediately upon attack by Special Weapons.

b. Report will include: Estimated casualties, extent of damage within areas; estimated extent of contamination; and any other pertinent information available.

c. Thereafter, at 6 hour intervals, supplementary flash reports will be submitted through channels to this headquarters listing all of the above information plus any other pertinent data which would be of value to this or higher headquarters.

CHESTER L. SLUDER
Colonel, USAF

Authenticated:
William F. Mandt
WILLIAM F. MANDT
Lt. Colonel USAF
Dep. for Opns.

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SECRET - SWARMER - SECRET

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D/M Report Form No. 1 (Daily as of 2400 hrs)

TO: Commanding General, Task Force Air Force

FROM: (Applicable Unit)

(a) Number aircraft on hand

(b) Number aircraft in commission

(c) Number aircraft ACCP

(d) Number aircraft out for maintenance

(e) Number aircraft lost from accidents

(f) Number aircraft damaged (simulated)

(g) Number aircraft destroyed (simulated) (f) & (g) as ruled by Air Umpires)

(h) Number hours flown

(i) Amount of fuel consumed by type in gallons (Aviation)

(j) Amount of Engine oil consumed by type on gallons (Aviation)

(k) Oxygen consumed (No. of sylinders)

(l) Number engine changes

(m) Number vehicles on hand

(n) Number vehicles VDP

(o) Number vehicles out for maintenance

(p) Number vehicles lost through accident

(q) Amount gasoline consumed (vehicles)

(r) Amount of oil consumed in quarts (vehicles)

(s) Number special purpose vehicles on hand

(t) Number special purpose vehicles VDP

(u) Number special purpose vehicles out for maintenance

(v) Number special purpose vehicles lost through accident

Note: The above information will be furnished by breakdown according to symbol and will include only those portions that pertain to the unit.

TAB A

For Example:

(a) 25

(b) 20

(d) 2

(h) 30

(i) 6000 dash 100/130

(j) 100 gals 1120
etc.

d. Above report would indicate that as of midnight 25 A/C are on hand, 20 A/C in commission; no A/C AOCP; 2 A/C out for maintenance; 30 hours flown that day. 6000 gallons of 100/130 grade AvGas consumed that day: 100 gallons of 1120 oil consumed that day: etc.

HEADQUARTERS
MANEUVER COMMANDER
EXERCISE SWARMER
Fort Bragg, North Carolina

General Plan, Exercise Swarmer

Changes)
No. 5)

22 March 1950

I. All previous changes are included herein. Changes 1 thru 4 are rescinded.

II. Cover letter: Date is changed from 6 February 1950 to 17 February 1950.

III. The following general changes apply to the General Plan and to all Annexes and Appendices thereto.

A. All references to Fort Jackson and Congaree Airfield, S.C. are changed to read: "Greenville Air Force Base, S.C." except as indicated in IV below.

B. All references to Tactical Air Force (Prov) are changed to read: "Air Task Force SWARMER" except as indicated in par 3b(4) to General Plan.

IV. The following specific changes are applicable to paragraphs as indicated:

GENERAL PLAN:

I. General

* * * * * * * * * *

3. Situation:

* * * * * * * * *

b. Friendly

* * * * * * * *

(2) Theater Army, composed of the V, X, XI, and XII Corps, has the mission of defending the Gulf and Atlantic coastline from the Mississippi - Louisiana boundary to Elizabeth City, N. C. with Corps mission as follows:

* * * * * * * *

(b) X Corps defends the Gulf Coast from the Mississippi - Louisiana boundary to Applachicola, Florida.

* * * * * * *

(3) Theater Air Force has the mission of the air defense of the Gulf and Atlantic coastline from the

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Incl #6

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the Mississippi - Louisiana boundary to Elizabeth City, N. C. and the Tactical Air Support of units of the Third Army as determined by SET.

(4) Delete and substitue therefor: "With the AGGRESSOR penetration into the Carolinas, SET establishes TASK FORCE "SWARMER" for the purpose of mounting an airborne operation to secure the Camp Mackall, N.C. Fort Bragg, N.C. - Fayetteville, N.C. area, and to dislodge AGRESSOR from the Atlantic seacoast. To accomplish this, V Corps is released from the Theater Army and Tactical Air Force (Prov) is released from the Theater Air Force, and are assigned to TASK FORCE "SWARMER". The 11th and 82nd Airborne Divisions and the 3rd Infantry Division (CPX only) are assigned to V Corps. AIR TASK FORCE "SWARMER" is established (General Order Number 8, Headquarters - Maneuver Commander, Exercise SWARMER, 16 March 1950), and is assigned the following USAF units:

Tactical Air Force (Provisional)	
4th Fighter-Interceptor Wing	3 Squadrons (Ftr) 2 Squadrons (Lt (Bomber)
20th Fighter-Bomber Wing	3 Squadrons
314th Troop-Carrier Wing	6 TC Squadrons
62nd Troop-Carrier Group	1 TC Squadron
161st TAC Reconnaissance Sq	1 Squadron
Navy Air Group	5 Squadrons
VMR 153	1 TC Squadron
Strategic Air Transport Wing (Prov)	MATS
363rd Reconnaissance Tech Squadron	1 Squadron
502nd TAC Control Group (-)	
934th Signal Bn	

Due to the commitment of all U.S. Forces in the Southeastern Theater, a ground link-up with the airborne forces is not contemplated for more than 30 days, and therefore supply must be maintained by airlift.

* * * * * * * * * *

II. Concept

5. Mission - Add paragraph "i"

* * * * * * * * * *

i. To test the feasibility of supporting and military combat operation by strategic airlift.

* * * * * * * * * *

10. Administrative Arrangements: Delete paragraphs as indicated and substitute therefor:

* * * * * * * * * *

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d. The Commanding General, Fort Bragg, is responsible for:

Add:

(3) The provision of Exchange facilities for troops stationed at Greenville Air Force Base, as agreed and coordinated with the Commander Carolina Base Section.

e. The Commanding General, Fort Jackson, is responsible for:

(1) Delete entire sub-paragraph.

(2) Redesignate to be (1).

f. The Commanding General, V Corps, is responsible for:

* * * * * * * * *

(3) Conduct of United States Forces Army tactical operations, training, administration, and logistical support for forces under his command during the period 1 April - 8 May 1950.

* * * * * * * * *

(5) Acting as Commander, Carolina Base Section prior to 20 March 1950 for planning of administration and logistical support to V Corps during the period 1 April - 8 May 1950.

ANNEX I

1. Command Responsibilities: Amend to read

* * * * * * * * * *

b. United States Forces, (Task Force SWARMER): Lieutenant General John R Hodge USA, will command Task Force SWARMER, utilizing Maneuver Headquarters Staff.

* * * * * * * * * * *

(3) Carolina Base Section: Brigadier General Paul F Yount.

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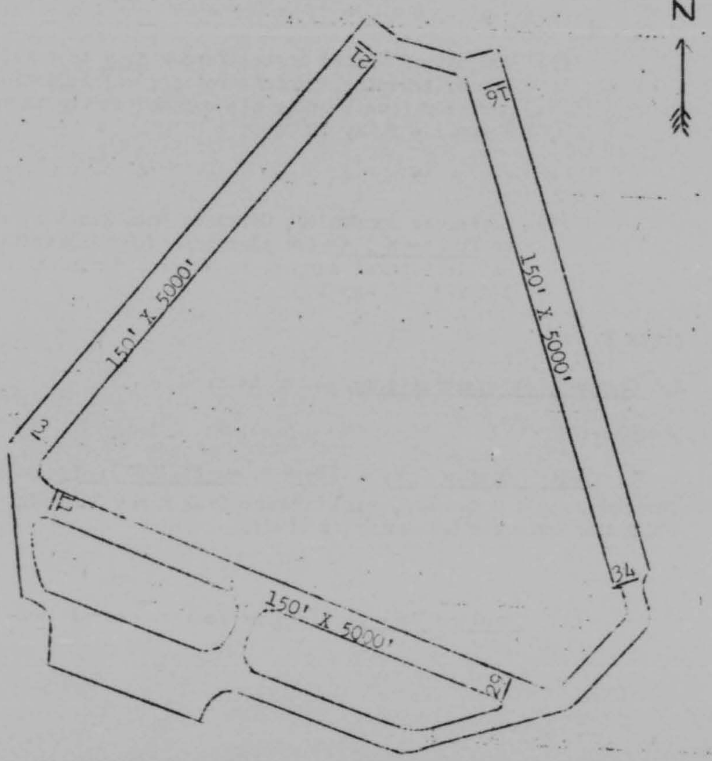
ANNEX II

Incl 2 to Annex II
General Plan -
Exercise SWARMER

AIRFIELD - CAMP MACKALL, N. C.

Elevation - 350 feet
Runways - Concrete
Location - 28.5 Miles
West Southwest of Pope AFB
Estimated load limits:
  54,000 lbs Continuous use
  80,000 lbs occasional use
C-54 is largest a/c that has landed
 (Limited by length of runways)



ANNEX III

3 g. The Commanding General, Fort Jackson, is responsible for:

(1) Delete entire sub-paragraph.

(2) Redesignate [illegible] (1).

* * * * * * * * *

Add:

31. The Commanding Officer, Greenville Air Force Base is responsible for: Provision of bivouac areas, bulk gasoline storage facilities, water points and other minor facilities, as agreed with the Commanding Generals, V Corps and Air Task Force SWARMER and the Commander Carolina Base Section.

ANNEX IV

Paragraph 1, is amended to read as follows:

1. Personnel

a. Unchanged

b. Troop Strength - Morning reports will be prepared and forwarded in accordance with SR 345-400-1 or AFR 31-6. Units participating in this Exercise will forward morning reports as follows:

(1) Army Units

(a) Third Army Units

1. Original copy of morning reports will be forwarded to: The Commanding General, Headquarters Third Army, Attention: Detachment "A", 25 Machine Records Unit (Mobile), Ft McPherson, Georgia.

2. A fourth copy of the morning report will be prepared on 3AA Form No. 27, dated 1 April 1950, and the special strength data on the right side of this form will be forwarded to the Commanding Officer, 25th Machine Records Unit (Mobile), Ft Bragg, North Carolina for all units participating in Exercise SWARMER beginning 1 April through 5 May 1950 as follows:

a. For units located in the Fort Bragg-Camp Mackall area: By courier not later than 1300 the day following the morning report date.

b. For units located outside the Fort Bragg-Camp Mackall area: Will be mailed by 0900 hours daily.

3. Forms 3AA 27, dated 1 April 1950, will be picked up from Postal Officers, Postal Concentration Centers upon arrival in Maneuver area

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(b) Other than Third Army Units

1. Original copy of morning reports will continue to be forwarded to MRU's servicing Army of Assignment as in the past.

2. A fourth copy of the morning report will be prepared on 3AA Form 27, dated 1 April 1950, and the special strength data on the right side of this form will be forwarded to the Commanding Officer, 25th Machine Records Unit (Mobile), Ft Bragg, North Carolina for all units participating in Exercise SWARMER beginning 1 April through 15 May 1950 as follows:

a. For units located in the Fort Bragg-Camp Mackall area: By courier not later than 1300 the day following the morning report date.

b. For units outside the Fort Bragg- Camp Mackall area: Will be mailed by 0900 hours daily.

3. Forms 3AA 27, dated 1 April 1950, will be picked up from Postal Officers, Postal Concentration Centers upon arrival in Maneuver area.

(2) Unchanged

(3) Unchanged

(c) Amended to be sub-paragraph 1c

(d) Amended to be sub-paragraph 1d.

e. Unchanged. (Do not change references to Fort Jackson in (1) and (5).)

f. Unchanged.

g. * * * * * * * * *

(C) Amend to read: "- - Commanding General, Fort Bragg and the Commanding Officers of - -".

2 a. Amend to read: "----- The Commander, Carolina Base Section will effect similar coordination for South Carolina."

ANNEX V

1c. Command Posts will be located as follows:

* * * * * * * * *

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Hq V Corps	Outer Camp Mackall, N. C.
Hq, Air Task Force SWARMER	Outer Camp Mackall, N. C.
Hq, Carolina Base Section	Outer Camp Mackall, N. C.

* * * * * * * * *

4. USAF Responsibilities

a. Amended to read: "----(2) TADC's for the Air Task Force SWARMER"

* * * * * * * * * *

Add:

d. All elements and equipment of the 502nd Tactical Control Group (to include CPS 5) to be used in the airhead will be airlifted into Camp Mackall prior to the start of the maneuver period. After arrival at Camp Mackall elements of the 502nd Tactical Control Group may be moved administratively into selected operating locations. Details incidental to this operation will be resolved by the Commanding General, Air Task Force SWARMER.

* * * * * * * * * *

6. Army Forces Responsibilities

Add: c. V Corps will be responsible for providing communications facilities for headquarters, Carolina Base Section Command.

7. US Navy Responsibilities

Delete: Sub-paragraph b.

9. Communications Troop List

Add: f. Under the provisions of sub-paragraph c above:

(1) "A" Company, 51st Signal Operations Battalion is assigned to V Corps.

(2) The 24th Signal Service Battalion (as augmented) is placed under the operational control of the Maneuver Commander.

* * * * * * * *

ANNEX VI Troop Lists

ANNEX VI Revised and reprinted on 20 March 1950. Destroy previous copies.

ANNEX VII

3. Organizational Chart for Exercise SWARMER.

In Aggressor AIR FORCE HQ box add (3), Box should read:
Air Force Hq
(31st Fighter Wing)
(3)

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Amend Note (1) to read:
(1) Hq Task Force Swarmer staffed by Maneuver Commander's Staff.

4. Organizational Chart for Maneuver Headquarters:

"Joint Exercise Information Bureau" is amended to read: "Office of Public Relations"

ANNEX IX

I - ARMY

Delete par 6 and substitute the following:

6. "Payment of troop units will be as directed in Annex IV, Administrative Instructions. Individuals on duty with Maneuver Headquarters and the Umpire Group will be paid by the Commanding General, Fort Bragg."

Delete par 10 and substitute the following:

10. "Payment of Air Force units will be as directed in Annex IV, Administrative Instructions. Individuals on duty with the Maneuver Headquarters and the Umpire Group will be paid by the Commanding General, Fort Bragg."

BY COMMAND OF LIEUTENANT GENERAL MUSTAD:

RIDGELY GAITHER
Brigadier General, USA
Chief of Staff

OFFICIAL

Robert D. Savage

ROBERT D. SAVAGE
Captain, Cavalry
Acting Adjutant General

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ANNEX VI - PART ONE
ARMY TROOP LIST - REVISED
I U. S. FORCES

20 Mar 50

UNIT	TO & E	DATE	AUTHORIZED STRENGTH O-FMO-WO-EM-AGG	PRESENT STATION	PRESENT ASSIGNMENT	INITIAL MANEUVER STATION	MANEUVER ATTACHMENT
Hq & Hq Co, V Corps	100-1-& 2	Jan 45	82-0-18-231-331	Ft. Bragg	3rd A	Cp. Mackall	TF SWARMER
11th A/B Div	71 NS	49	496-0-38-7440-7974	Cp Campbell	2nd A	Greenville AFB (1 RCT at Campbell)	V
11th AC Recon Co	17-57-20	Apr 49	5-0-1-148-154	Cp Campbell	2nd A	Greenville AFB	V
11th CIC Det	30-500	Sep 48	3-0-1-3-7	Cp Campbell	2nd A	Greenville AFB	V
82nd A/B Division	71 NS	49	809-0-125-12776-13710	Ft Bragg	3rd A	Cp Mackall	V
82nd AC Recon Co	17-57-20	Apr 49	5-0-1-148-154	Ft Bragg	3rd A	Cp Mackall	V
82nd CIC Det	30-500	Sep 48	4-0-2-8-14	Ft Bragg	3rd A	Cp Mackall	V
3rd Inf. Division (Staff CPX only)	7 N	Jul 48	100-0-5-45-150	Ft Benning	3rd A	Ft Benning	V
2nd Cml Mortar Bn	3-25	Mar 49	33-0-1-512-540	Army Cml Cen	C Cml C	Cp Mackall	V
68th Cml Smoke Gen Co	3-267	Mar 49	5-0-0-113-118	Army Cml Cen	C Cml C	Cp Mackall	V
544th FA Bn (155 How) TR Dn (1 Ltrd Btry only)	6-335-20	Mar 49	28-0-3-471-502 (-Bn Hq Co,2Ltrd Btrys)	Cp Campbell	2nd A	Greenville AFB	V
98th FA Bn (155 How) Tr Dn	6-335-20-20	Mar 49	28-0-3-471-502	Ft Bragg	3rd A	Cp Mackall	V
Co A, 728 MP Bn (- 1 Plat)	19-55	Apr 49	4-0-0-158-162	Ft Sheridan	5th A	Cp Mackall	V
5th MP Plat, Corps	19-77	Aug 44	3-0-0-42-45	Ft Bragg	3rd A	Cp Mackall	V
73rd Engr Combat Bn (-1 Co)	5-35	Sep 48	24-0-4-513-541	Cp Hood	4th A	Greenville AFB	V
185th Engr Combat Bn (-2 CO)	5-35	Sep 48	24-0-4-513-541	Cp Campbell	2nd A	Cp Mackall	V
Hq & Hq Det 19th Engr Comb Gp	5-192	Nov 49	15-0-1-72-88	Cp Campbell	2nd A	Cp Mackall	V

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ARMY TROOP LIST - REVISED (CONT'D)
I U. S. FORCES

20 Mar 50

UNIT	TO & E	DATE	AUTHORIZED STRENGTH O-FMO-WO-EM-AGG	PRESENT STATION	PRESENT ASSIGNMENT	INITIAL MANEUVER STATION	MANEUVER ATTACHMENT
533d Engr Tech Int Det	5-399 T	Apr 45	3-0-0-6-9	Ft. Bragg	3rd A	Cp. Mackall	V
62nd Engr Topo Co, Corps	5-167	Jul 49	4-0-2-102-108	Ft. Bragg	3rd A	Cp. Mackall	V
188th Med Bn Hq & Hq Det	8-26-20	Jul 49	4-0-1-22-27	Ft Bragg	3rd A	Cp. Mackall	V
558th Med Coll Co (-1 Plat)	8-27-20	Jul 49	5-0-0-104-109	Ft. Bragg	3rd A	Cp. Mackall	V
421st Med Coll Co (-1 Plat)	8-27	Oct 48	5-0-0-104-109	Ft. Benning	3rd A	Greenville AFB	V
618th Med Clr Co (-1 Plat)	8-28	Jan 49	8-0-1-94-103	Ft. Bragg	3rd A	Cp. Mackall	V
514th Med Clr Co	8-28	Jan 49	8-0-1-94-103	Ft. Benning	3rd A	Greenville AFB	V
559th Med Amb Co (-2 Plats)	8-317	May 49	3-0-0-68-71	Ft. Bragg	3rd A	Cp. Mackall	V
560th Med Amb Co (-1 Plat)	8-317	May 49	3-0-0-68-71	Cp. Campbell	2nd A	Greenville AFB	V
121st Evac Hosp	8-581	Jan 49	31-34-1-207-273	Ft. Benning	3rd A	Greenville AFB	V
171st Evac Hosp	8-581	Jan 49	31-34-1-207-273	Ft. Bragg	3rd A	Cp. Mackall	V
2nd Mobile Army Surg Hosp	8-571	Oct 48	13-10-1-77-101	Ft. Bragg	3rd A	Cp. Mackall	V
335th Ord Bn Hq & Hq Det	9-76	Nov 48	5-0-1-31-37	Ft. Bragg	3rd A	Cp. Mackall	V
416th Ord Med Maint Co	9-7	Sep 48	4-0-1-152-157	Ft. Bragg	3rd A	Cp. Mackall	V
92nd Ord Med Maint Co	9-7	Sep 48	4-0-1-152-157	Cp. Campbell	2nd A	Greenville AFB	V
538th Ord Med Auto Maint Co	9-127	Nov 48	4-0-1-[illegible]-107	Ft. Bragg	[illegible] A	Cp. Mackall	V

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ARMY TROOP LIST-REVISED (CONT'D)
I U. S. FORCES

20 Mar 50

UNIT	TO & E	DATE	AUTHORIZED STRENGTH O-FMO-WO-EM-AGG	PRESENT STATION	PRESENT ASSIGNMENT	INITIAL MANEUVER STATION	MANEUVER ATTACHMENT
15th Ord Exp Disp Sqd	9-500EB	Oct 44	1-0-0-7-8	Ft. Bragg	3rd A	Cp. Mackall	V
14th Qm Bn Hq & Hq Det	10-536-20	Jan 50	5-0-1-27-33	Ft. Bragg	3rd A	Cp. Mackall	V
580th Qm Service Co	10-67-20	Jan 50	4-0-0-144-148	Ft. Bragg	3rd A	Cp. Mackall	V
58th Qm Salvage Co	10-187	Jul 49	2-0-0-134-136	Cp. Campbell	2nd A	Greenville (Co-) Cp. Mackall (1 Plat)	V
505th Qm Reclm & Maint	10-237	Mar 49	5-0-0-183-188	Cp. Campbell	2nd A	Greenville AFB	V
1st Signal Sv Gp	11-500	Sep 44	5-0-1-14-20	Ft. Bragg	3rd A	Cp. Mackall	V
4th Signal Bn, Corps	11-15N	Apr 49	37-0-5-918-960	Ft. Bragg	3rd A	Cp. Mackall	V
Co A, 51st Signal Bn, Opns	11-95	May 44	5-0-1-180-186	Ft. Meade	2nd A	Cp. Mackall	V
20th Signal AGL Co	11-547	Aug 45	5-0-0-182-187	Ft. Bragg	3rd A	Cp. Mackall	V
53d Sig Serv Co (Corps Type)(RI)(-Det)	11-500	Sep 44	10-0-1-236-247	Vint-Hills Farms, Va	ASA	Cp. Mackall	V
Liaison Det, ASA			2-0-0-3-5	Vint-Hills Farms, Va	ASA	Cp. Mackall	V

(NOTE: Detachments of the above Signal Units will be attached to Carolina Base Section, as directed by J-5, this headquarters, (after arrival of units in Maneuver Area).

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ARMY TROOP LIST - REVISED (CONT'D)
I U. S. FORCES

20 Mar 50

UNIT	TO & E	DATE	AUTHORIZED STRENGTH O-FMO-WO-EM-AGG	PRESENT STATION	PRESENT ASSIGNMENT	INITIAL MANEUVER STATION	MANEUVER ATTACHMENT
52nd Trans Trk Bn Hq & Hq Det	55-16	Mar 49	7-0-1-52-60	Ft. Benning	3rd A	Cp, Mackall	V
396th Trans Trk Co	55-17	Aug 48	3-0-1-72-76	Ft. Benning	3rd A	Cp. Mackall	V
107th Finance Disb Sec	14-500	Mar 49	2-0-1-21-24	Ft. Bragg	3rd A	Ft. Bragg	V
525th MI Serv Co (Including 526, 527, 528 MI Serv Plats) (-Det)	30-500	Oct 48	15-0-0-66-81	Ft. Bragg	3rd A	Cp. Mackall	V
205th MI CIC Det	30-500	Sep 48	4-0-2-18-24	Ft. Bragg	3rd A	Cp. Mackall	V
316th MI CIC Det	30-500	Sep 48	6-0-4-10-20	Ft. Bragg	3rd A	Cp. Mackall	V

(NOTE: Portions of the above MI units will be attached to Maneuver Headquarters and Carolina Base Section, as directed by (J-2, this Headquarters, after arrival of units in Maneuver Area).

ARMY TROOP LIST REVISED (CONT'D)
I U. S. FORCES

20 MAR 50

UNIT	TO & E	DATE	AUTHORIZED STRENGTH C-FWO-WO-EM-AGG	PRESENT STATION	PRESENT ASSIGNMENT	INITIAL MANEUVER STATION	MANEUVER ATTACHMENT
Hq & Hq Co, 7th Trans Med Port (Hq CRS)	55-120-1N	May 44	60-0-0-184-244	Ft Hamilton	COT	Cp Mackall	TF Swarmer
59th Cml Maint Co	3-47	Nov 44	2-0-0-72-74	Army Cml Cen	C Cml C	Cp Mackall	CB
94th Engr Cons Bn	5-315	Mar 49	16-0-6-530-552	Ft Belvoir	C Eng	Cp Mackall	CB (Initially V)
630th Engr Lt Equip Co	5-367	Oct 48	5-0-1-142-148	Cp Campbell	2nd A	Greenville AFB	CB
1 Plat, 712 Engr Depot Co	5-47	Dec 44	1-0-0-32-33	Granite City Ill	5th A	Greenville AFB	CB
536th Engr Maint Co	5-157	Aug 44	4-0-2-183-189	Ft Bragg	3rd A	Greenville AFB(1 maint plt) Cp Mackall (Co-)	CB
74th Engr Hv Equip Co	5-316	Mar 49	4-0-1-164-167	Ft Bragg,	3rd A	Cp Mackall	CB
512 Engr Dump Tk Co	5-324	Nov 48	4-0-1-80-85	Ft Belvoir	C Eng	Cp Mackall	CB (Initially V)
64th Field Hosp	8-510	Jul 49	17-18-1-147-183	Ft Bragg	3rd A	Cp Mackall (Hosp-) Greenville AFB (1 Hosp Unit)	CB
1 Plat 421st Med Coll Co	8-27-20	Jul 49	1-0-0-22-23	Ft Benning	3rd A	Greenville AFB	CB
1 Plat 558th Med Coll Co	8-27-20	Jul 49	1-0-0-22-23	Ft Bragg	3rd A	Cp Mackall	CB
1 Plat 559th Med Amb Co	8-317	May 49	1-0-0-16-17	Ft Bragg	3rd A	Cp Mackall	CB
1 Plat 560th Med Amb Co	8-317	May 49	1-0-0-16-17	Cp Campbell	2d A	Greenville AFB	CB

ARMY TROOP LIST REVISED (CONT'D)
I U. S. FORCES

20 Mar 50

UNIT	TO & E	DATE	AUTHORIZED STRENGTH C-FMO-WO-EM-AGG	PRESENT STATION	PRESENT ASSIGNMENT	INITIAL MANEUVER STATION	MANEUVER ATTACHMENT
6th Med Depot Co (2 S & I Secs)	8-667	Nov 48	2-0-2-48-52	St Louis	5th A	Cp Mackall (1 Sec) Greenville AFB (1 Sec)	CB
Hq Co 772 MP Bn	19-55	Apr 49	[illegible]	Ft Meade	2nd A	Greenville AFB	CB
Co C 772 MP Bn	19-55	Apr 49	5-0-0-129-134	Ft Meade	2nd A	Greenville AFB	CB
Co C 716 MP Bn	19-55	Apr 49	5-0-0-129-134	Gov Island	1st A	Cp Mackall	CB
1st MP CID	19-500 RJ	Sep 45	2-0-5-6-13	Ft Dix	GHM Gr	Greenville AFB	CB
4th Ord Bn Hq & Hq Det	9-76	Nov 48	5-0-1-31-37	Ft Knox	2nd A	Greenville AFB	CB
514th Ord Med Auto Maint Co	9-127	Nov 48	4-0-1-102-107	Ft Knox	2nd A	Greenville AFB	CB
65th Ord Am Co	9-17	Sep 49	4-0-1-199-204	Ft Knox	2nd A	Greenville AFB (Co-) Cp Mackall (1 Plat)	CB CB
71st Ord Depot Co	9-57	Oct 48	4-0-4-164-172	Ft Benning	3rd A	Greenville AFB	CB
142nd QM Bn Hq&Hq Det	10-536-20	Jan 50	5-0-1-27-33	Cp Campbell	2nd A	Greenville AFB	CB
502nd QM Fld Sv Co	10-48-20	Jul 49	4-0-0-113-117	Cp Campbell	2nd A	Greenville AFB	CB
599th QM Fld Sv Co	10-48-20	Jul 49	4-0-0-113-117	Ft Bragg	3rd A	Cp Mackall	CB
531st QM Petrol Sup Co	10-77-20	Jul 49	3-0-0-110-113	Ft Bragg	3rd A	Greenville AFB (Co-) Cp Mackall (1 Plat)	CB CB
108th QM Bakery Co	10-147-CS	Oct 44	4-0-0-99-103	Ft Bragg	3rd A	Greenville AFB (1 Plat) Cp Mackall (Co-)	CB CB

ARMY TROOP LIST REVISED (CONT'D)
I U. S FORCES

20 Mar 50

UNIT	TO & E	DATE	AUTHORIZED STRENGTH O-FO-WO-EM-AGG	PRESENT STATION	PRESENT ASSIGNMENT	INITIAL MANEUVER STATION	MANEUVER ATTACHMENT
899th QM Ldry Co	10-167-20	Jul 49	4-0-0-183-187	Ft Bragg	3rd A	Greenville AFB (1 Plat) Cp Mackall (Co-)	CB CB
20th Qm Sub Sup Co	10-197	Nov 48	4-0-1-156-161	Ft Benning	3rd A	Greenville AFB (1 Plat) Cp Mackall (Co-)	CB CB
563d Qm Depot Sup Co (- 1 Plat)	10-2270S	Mar 45	4-0-1-142-147	Cp Lee	OQMG	Greenville AFB (Co-) Cp Mackall (1 Plat)	CB CB
1 Plat, 287th Qm Refrig Co	10-247	Feb 44	3-0-0-80-83	Cp Lee	OQMG	Cp Mackall	CB
821st Qm Fum & Bath Co	10-257	Sep 43	4-0-0-176-180	Cp Campbell	2nd A	Greenville AFB(1 Plat) Cp Mackall (Co-)	CB CB
Det 181st Sig Dep Co Repair Sec 2S & I Secs)	11-107	Feb 45	2-0-0-32-34	Ft Meade	2nd A	Greenville AFB	CB
11th Trans Port Bn Hq & Hq Det	55-116	Mar 44	3-0-1-13-17	Ft Eustis	COT	Greenville AFB	CB
113th Trans Port Co (Type B)	55-118	Oct 48	6-0-0-187-193	Ft Eustis	COT	Greenville AFB	CB
118th Trans Port Co (Type B)	55-118	Oct 48	6-0-0-187-193	Ft Eustis	COT	Cp Mackall	CB
870th Trans Port Co (Type A)	55-117	Oct 48	2-0-0-202-204	Ft Eustis	COT	Greenville AFB	CB
866th Trans Port Co (Type A)	55-117	Oct 48	2-0-0-202-204	Ft Eustis	COT	Cp Mackall	CB
55th Trans Trk Bn Hq & Hq Det	55-16	Mar 49	7-0-1-52-60-	Ft Eustis	COT	Greenville AFB	CB

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ARMY TROOP LIST REVISED (CONT'D)
I U. S. FORCES

UNIT	TO & E	DATE	AUTHORIZED STRENGTH O-WO-EM-AGG	PRESENT STATION	PRESENT ASSIGNMENT	INITIAL MANEUVER STATION	MANEUVER ATTACHMENT
49th Trans Trk Co	55-17	Aug 48	3-0-1-72-76	Ft Eustis	COT	Greenville AFB	CB
515th Trans Trk Co	55-17	Aug 48	3-0-1-72-76	Ft Knox	2nd A	Greenville AFB	CB
42d Trans Trk Co	55-17	Aug 48	3-0-1-72-76	Ft Dix	1st A	Cp Mackall	CB
48th Trans Trk Co (Hv)	55-18	Apr 49	3-0-1-76-80-	Ft Eustis	COT	Greenville	CB
592nd Trans Traf Reg Det (#)	55-500	Sep 44	14-0-0-71-85	Ft Eustis	COT	Cp Mackall	CB
112th AFU (Type F)	12-605	Dec 48	1-0-0-11-12	Ft Bragg	3rd A	Cp Mackall	CB
117th AFU (Type F)	12-605	Dec 48	1-0-0-11-12	Ft Knox	2nd A	Greenville AFB	CB
25th MPU (Type Z) (M)	12-317	Oct 44	3-0-0-51-54	Ft McPherson	3rd A	Cp Mackall	CB
1 Plat 95th Cml Sv Co			3-0-0-73-76	Army Cml Cen	C Cml C	Greenville AFB	CB
Comp Co 3rd Bn 221st Inf	Unk	Unk	4-0-0-167-171	Unk, Fla	Fla NG	Present Station	CB
19th AAA Gp Hq & Hq Btry	44-12-20	Jun 49	11-0-3-62-76	Ft Meade	2nd A	Cp Mackall	CB (Later V)
503rd AAA Opns Det	44-7	Jun 49	3-0-0-49-52	Ft Meade	2nd A	Cp Mackall	CB (Later V)
4th AAA AW Bn (M)	44-25-20	Oct 48	29-0-3-687-719	Ft Meade	2nd A	Cp Mackall	CB (Later V)
39th AAA AW Bn (M)	44-25-20	Oct 48	29-0-3-687-719	Ft Meade	2nd A	Greenville AFB	CB (Later V)

ARMY TROOP LIST REVISED (CONT'D)
II [illegible] FORCES

20 Mar 50

UNIT	TO & E	DATE	AUTHORIZED STRENGTH O-WO-NO-EM-AGG	PRESENT STATION	PRESENT ASSIGNMENT	INITIAL MANEUVER STATION	MANEUVER ATTACHMENT
GHQ Aggressor			4-0-0-0-4	Ft Riley	5th A	Ft Bragg	15th Inf
15th Inf Regt (-1 Bn) (Hq Aggressor Army Forces)	7-11N		114-0-8-1958-2080	Ft Benning	3rd A	Ft Bragg	
44th Hv Tank Bn	17-35-20	May 49	27-0-4-508-539	Ft Bragg	3rd A	Ft Bragg	15th Inf
70th AAA Gun Bn (90mm)	44-15-20	Aug 49	23-0-3-568-594	Ft Meade	2nd A	Ft Bragg	15th Inf
41st FA Bn (105 How)	6-25N		36-0-1-550-587	Ft Benning	3rd A	Ft Bragg	15th Inf
Co B 10th Engr Bn	5-17N		3-0-0-100-103	Ft Benning	3rd A	Ft Bragg	15th Inf
47th Engr Cam Bn (Hq Co & Co A only)	5-95	Jan 45	14-0-0-124-138	Ft Riley	5th A	Ft Bragg	15th Inf
Sig Co (Special) 3rd Hq Sp Trps	11-7S	Apr 44	1-0-0-7-8	Ft Riley	5th A	Ft Bragg	15th Inf
Tactical Info Det, 5021st ASU			4-0-0-20-24	Ft Riley	5th A	Ft Bragg	15th Inf
Co B 29th Sig Cons Bn, (less 1 Plat)	11-25	Jun 49	6-0-0-172-178	Ft Bliss	4th A	Ft Bragg	15th Inf
565th Qm GR Co	10-297	Nov 43	4-0-0-95-99	Ft Bragg	3rd A	Ft Bragg	15th Inf
1 Plt, 618th Med Clr Co	8-28-20	Jul 49	2-0-0-15-17	Ft Bragg	3rd A	Ft Bragg	15th Inf
1 Plt, 559th Med Amb Co	8-317	May 49	1-0-0-16-17	Ft Bragg	3rd A	Ft Bragg	15th Inf

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ARMY TROOP LIST REVISED (CONT'D)
II AGGRESSOR FORCES

UNIT	TO & E	DATE	AUTHORIZED STRENGTH O-FWO-WO-EM-AGG	PRESENT STATION	PRESENT ASSIGNMENT	INITIAL MANEUVER STATION	MANEUVER ATTACHMENT
17th Ord Exp Disp Sq	9-500EP	Oct 44	1-0-0-7-8	Ft Knox	2d A	Ft Bragg	15th Inf
1 Plt 503d MP Bn	19-35	Dec 48	2-0-0-62-64	Ft Bragg	3rd A	Ft Bragg	15th Inf
3d Ord Med Auto Maint Co	9-127	Nov 48	4-0-1-102-107	Ft Dix	1st A	Ft Bragg	15th Inf
503d MI CIC Det	30-500	Sep 48	10-0-0-15-25	Ft Meade	2d A	Ft Bragg	15th Inf
Det, 525th MI Sv Co	30-500	Sep 48		Ft Bragg	3rd A	Ft Bragg	15th Inf
Det, 53d Sig Sv Co	11-500	Sep 44		Vint-Hill Farms, Va	ASA	Ft Bragg	15th Inf
Liaison Det, ASA			2-0-0-3-5	AHS, Va	ASA	Ft Bragg	15th Inf
Spec Comm Det, ASA			0-0-0-9-9	AHS, Va	ASA	Ft Bragg	15th Inf
Comm MI Team, Wire			1-0-0-6-7	AHS, Va	ASA	Ft Bragg	15th Inf
Det 53d Sig Ser Co			0-0-0-20-20	Vint-Hills Farms, Va	ASA	Ft. Bragg	15th Inf
9466 TSU (Electronics Warfare)			2-0-0-50-52	Ft Monmouth	CC Sig	Ft Bragg	Aggressor

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ARMY TROOP LIST REVISED (CONT'D)
III MANEUVER ADMINISTRATIVE FORCES

20 Mar 50

UNIT	TO & E	DATE	AUTHORIZED STRENGTH O-FO-WO-EM-AGG	PRESENT STATION	PRESENT ASSIGNMENT	INITIAL MANEUVER STATION	MANEUVER ATTACHMENT
Hq Btry, V Corps Arty	6-501	Aug 49	22-0-1-89-112	Ft Bragg	3rd A	Ft Bragg	MC
Det, 181 Sig Depot Co (1 S & I Sec)	11-107	Feb 45	1-0-0-12-13	Ft Meade	2d A	Ft Bragg	MC
95th Mil Govt Gp	41-500	Jun 48	20-0-1-94-115	Ft Bragg	3rd A	Ft Bragg	Ump
28th Mil Gov Co	41-500	Jun 48	20-0-1-106-127	Ft Bragg,	3rd A	Ft Bragg	Ump
29th Mil Govt Co	41-500	Jun 48	20-0-1-106-127	Ft Bragg	3rd A	Ft Bragg	Ump
1 Plt Co B 29th Sig Cons Bn	11-25	Jun 49	2-0-0-86-88	Ft Bliss	4th A	Ft Bragg	Ump
25th Cml Decon Co	3-217N	Jan 50	4-0-0-126-130	Ft Bragg	3rd A	Ft Bragg	Ump
503d MP Bn (less 1 Plt)	19-35	Dec 48	10-0-3-393-406	Ft Bragg	3rd A	Ft Bragg	FB
95th Trans Car Co	55-19	Sep 48	5-0-0-76-81	Ft Bragg	3rd A	Ft Bragg	MC
Comp Sig Co (63d Sig Sv Co & 593d Sig Opns Co)			6-0-0-130-136	Ft Lewis	6th A	Ft Bragg	MC
24th Sig Sv Bn	11-500	Sep 44	21-0-0-244-265	Cp Gordon	3rd A	Ft Bragg	MC
581st Sig Co Rad Rel (2 Dets)	11-500	Sep 44	4-0-0-30-34	Cp Gordon	3rd A	Ft Bragg	MC
1 Plt, Co A, 728th MP Bn	19-55	Apr 49	1-0-0-50-51	Ft Sheridan	5th A	Ft Bragg	MC
Liasion Det ASA			2-0-0-2-4	Vint-Hills Farms, Va	ASA	Ft Bragg	MC
Det, 167th Sig Photo Co	11-37	Feb 44	4-0-0-16-20	Ft. Meade	2nd A	Ft. Bragg	MC

NOTE: FB-Fort Bragg
UMI-Chief Umpire
V-V Corps
CB-Carolina Base Section
MC-Maneuver Commander

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ANNEX VI-PART TWO
GENERAL PLAN
EXERCISE SWARMER

AIR FORCE TROOP LIST-Revised 20 March 1950
SECTION I
U.S.FORCES

RESTRICTED

UNIT	TO & E	DATE	OFF	AM	AGG	PRESENT STATION	ASGMT	MANEUVER BASE	REMARKS
HQ TAF (PROV)	GO 2 ConAC	11 Jan 50	40	62	102	Pope AFB, N.C.	TAC(OP)	Outer Camp Mackall	
4th Ftr-Int Wing Hq & Hq Sq	1-1011	24 Mar 48	30	64	94	Langley AFB, Va.	9th AF	Maxton Airport	Note # 1
4th Fighter Gp. Hq	1-1212	"	11	25	36	"	"	"	The Wg.Hq Airbase Gp,
334th Ftr Sq, Jet	1-1233	"	30	108	138	"	"	"	M&S Gp, & Medical Gp,will
335th Ftr Sq, Jet	1-1233	"	30	108	138	"	"	"	support the Operational
336th Ftr Sq, Jet	1-1233	"	30	108	138	"	"	"	Gp (or Gps) to the ex-
4th Airbase Gp,Hq & Hq Sq	1-8012	"	9	60	69	"	"	"	tent determined by GG ATF
4th Base Ser Sq	1-8018	"	2	64	66	"	"	"	SWARMER & Wing Commander
4th Installations Sq	1-8926	"	4	70	74	"	"	"	
4th Food Ser Sq	1-8015	"	4	102	106	"	"	"	
4th Comm Sq	1-8013	"	4	52	56	"	"	"	
4th Air Police Sq	1-8014	"	3	70	73	"	"	"	
4th M & S Gp, Hq	1-7012	"	4	10	14	"	"	"	
4th Maint. Sq	1-7213	"	9	121	130	"	"	"	
4th Supply Sq	1-7914	"	7	85	92	"	"	"	
4th Motor Vehicle Sq	1-8917	"	4	127	131	"	"	"	
4th Medical Gp, Hq	1-9012	18 Oct 48	14	67	81	"	"	"	
84th Bomb Sq(L), Jet	1-1143	24 Mar 48	55	193	248	"	"	Langley AFB,Va.	
85th Bomb Sq(L), Jet	1-1143	"	55	193	248	"	"	"	
20th Ftr-Bomber Wing,Hq&Hq Sq	1-1011	"	30	64	94	Shaw AFB, S.C.	14th AF	Shaw AFB, S.C.	Note # 1 Applies
20th Ftr Gp, Hq	1-1212	"	11	25	36	"	"	"	
55th Ftr Sq, Jet	1-1233	"	30	114	144	"	"	"	
77th Ftr Sq, Jet	1-1233	"	30	114	144	"	"	"	
79th Ftr Sq, Jet	1-1233	"	30	114	144	"	"	"	
20th Airbase Gp.Hq&Hq Sq.	1-8012	"	9	60	69	"	"	"	
20th Base Ser. Sq	1-8018	"	2	64	66	"	"	"	
20th Installations Sq	1-8926	"	4	70	74	"	"	"	
20th Food Ser Sq	1-8015	"	4	102	106	"	"	"	
20th Comm Sq	1-8013	"	4	52	56	"	"	"	
20th Air Police Sq	1-8014	"	3	70	73	"	"	"	

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UNIT	TO & E	DATE	O	AN	AGG	PRESENT STATION	ASGMT	MANEUVER BASE	REMARKS
20th M & S Gp, Hq	1-7012	24 Mar 48	4	10	14	Shaw AFB, S.C.	14th AF	Shaw AFB, S.C.	
20th Maint. Sq	1-7213	"	9	121	130	"	"	"	
20th Supply Sq.	1-7914	"	7	85	92	"	"	"	
20th Motor Vehicle Sq.	1-8917	"	4	127	131	"	"	"	
20th Medical Gp, Hq.	1-9012	18 Oct 48	14	67	81	"	"	"	
161st TAC Rcn Sq	1-1423	"	28	115	143	"	"	"	
62nd Troop Carrier Gp						McChord AFB, Wash	4th AF	Greenville AFB, S.C.	Note # 1 Applies
Squadron						"	"	"	
314th Troop Carrier Wing Hq	1-1011	24 Mar 48	30	64	94	Smyrna AFB, Tenn	14th AF	Maxton Airport, N.C.	Note # 1 Applies
314th TC Gp, Hq	1-1312	"	13	28	41	"	"	"	
50th TC Sq	1-1323	"	75	160	235	"	"	"	
61st TC Sq & 62nd TC Sq	1-1323	"	75	160	235	"	"	"	
316th TC Gp, Hq	1-1312	"	13	28	41	"	"	"	
36th TC Sq	1-1313	"	43	142	185	"	"	"	
37th TC Sq	1-1313	"	43	142	185	"	"	"	
2601 Assault TC Sq						"	"	"	
314th Airbase Gp, Hq & Hq Sq	1-8012	"	8	55	63	"	"	"	
314th Base Ser Sq	1-8018	"	2	64	68	"	"	"	
314th Installations Sq	1-8916	"	4	76	80	"	"	"	
314th Food Ser Sq	1-8015	"	4	115	119	"	"	"	
314th Comm. Sq	1-8013	"	4	52	56	"	"	"	
314th Air Police Sq	1-8014	"	3	70	73	"	"	"	
314th M & S Gp, Hq	1-7012	"	4	10	14	"	"	"	
314th Maint. Sq	1-7323	"	9	164	173	"	"	"	
314th Supply Sq	1-7314	"	7	77	84	"	"	"	
314th Motor Vehicle Sq	1-8317	"	4	121	125	"	"	"	
314th Medical Gp	1-9012	18 Oct 48	20	77	97	"	"	"	

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ANNEX VI - PART TWO
GENERAL PLAN
EXERCISE SWARMER

AIR FORCE TROOP LIST - Revised 20 March 1950
SECTION I
U.S. FORCES

RESTRICTED

UNIT	TO & E	DATE	O	AM	AGG	PRESENT STATION	ASGD	MANEUVER BASE	REMARKS
502nd TAC Control Gp, Hq	1-600	24 Jul 48	16	38	54	Pope AFB, N.C.	14th AF	Outer Camp Mackall, N.C.	
605th TAC Control Sq	1-600	"	20	210	230	"	"	"	
606th TAC Control Sq	1-600	"	16	38	54	"	"	"	Portion to Aggressor
607th TAC Control Sq	1-600	"	16	38	54	"	"	"	
934th Signal Bn.	1-335	2 Feb 44	26	329	355	Pope AFB, N.C.	14th AF	Outer Camp Mackall, N.C.	
VMR 153 (Marine TC) Squadron						Cherry Point, N.C.		Maxton Airport, N.C.	Aircraft will use Cherry Point as home Base and stage at Maxton
						"		"	
363rd Rcn Tech. Sq						Langley AFB, Va.		Outer Camp Mackall, N.C.	Operates w/62nd Topographic company.
CVG 2 (Navy Air Group)						Oceana NA S, Va.		Aceana NAAS, Va	
VF 22 (Ftr Squadron)						"		"	
VF 23 (Ftr Squadron)						"		"	
VF 24 (Ftr Squadron)						"		"	
VA 25 (Attack Squadron)						"		"	
VA 65 (Attack Squadron)						"		"	
Strategic Air Transport Wing (Prov)							MATS	Greenville AFB, S.C.	Supported Logistically by 14th AF. Not officially committed as yet.
Reserve Troop Carrier Units									
2nd Liaison Flight							ConAC	Maxton Airport, N.C.	As Determined.
4th Liaison Flight						Langley AFB, Va.	9th AF	As Selected	
3rd Liaison Flight						Pope AFB, N.C.	14th AF	As Selected	
AACS Det.						Lawson AFB, Ga.	14th AF	As Selected	
AACS Det.								Maxton Airport, N.C.	
AACS Det.								Mackall Airfield, N.C.	
								Greenville AFB, S.C.	

RESTRICTED

AIR FORCE TROOP LIST - Revised 20 March 1950
SECTION I
U. S. FORCES

	TO & E	DATE	O	AM	AGG	PRESENT STATION	ASGD	MANEUVER BASE	REMARKS
AWS Det								Maxton Airport, N.C.	
AWS Det								Mackall Airfield, N.C	
AWS Det								Greenville AFB, S.C.	
5th Liaison Flight (Helicopter)						Pope AFB, N.C.	14th AF	Pope AFB, N.C.	

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AIR FORCE TROOP LIST - Revised 20 March 1950
SECTION II
AGGRESSOR FORCES

UNIT	TO & E	DATE	O	AM	AGG	PRESENT STATION	ASGD	MANEUVER BASE	REMARKS
31st Fighter-Bomber Wing, Hq&Hq S	1-1011	24 Mar 48	30	64	94	Turner AFB, Ga.	14th AF	Langley AFB, Va.	Note #1 Applies
31st Ftr Gp, Hq	1-1212	"	11	25	36	"	"	"	
307th Ftr Sq. Jet	1-1233	"	30	114	144	"	"	"	
308th Ftr Sq. Jet	1-1233	"	30	114	144	"	"	"	
309th Ftr Sq. Jet	1-1233	"	30	114	144	"	"	"	
31st Airbase Gp, Hq & Hq Sq	1-8012	"	9	60	69	"	"	"	
31st Base Ser. Sq	1-8018	"	2	64	66	"	"	"	
31st Installations Sq	1-8920	"	4	70	74	"	"	"	
31st Food Ser Sq	1-8015	"	4	102	106	"	"	"	
31st Comm. Sq	1-8013	"	4	52	56	"	"	"	
31st Air Police Sq	1-8014	"	3	70	73	"	"	"	
31st M & S Gp, Hq.	1-7012	"	4	10	14	"	"	"	
31st Maint Sq	1-7013	"	9	121	130	"	"	"	
31st Supply Sq	1-7914	"	7	85	92	"	"	"	
31st Motor Vehicle Sq	1-8917	"	4	127	131	"	"	"	
31st Medical Gp.	1-9012	18 Oct 48	14	67	81	"	"	"	
78th Fighter Gp						Hamilton AFB, Calif	4th AF	Langley AFB, Va.	Note # 1 Applies
Ftr Squadron, Jet						"	"	"	
Det 502d TAC Control Gp	1-600					Pope AFB, N.C.	14th AF	As Selected	
Navy Night Fighters								Norfolk NAS, Va.	
8 VFN ACFT								"	
4 VAN ACFT								"	
162nd TAC Rcn Sq	1-433	24 Mar 48	64	153	217	Langley AFB, Va.	9th AF	Langley AFB Va.	
Det. 1st Shoran Bcn Unit	1-					Langley AFB, Va	9th AF	Ft Bragg N.C.	

HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK

O&T 354.2

14 April 1950

SUBJECT: Amendment to Directive for the Implementation of Joint Army - Air Force Exercise, Fiscal Year 1950 - "Swarmer"

TO: Commanding General, Tactical Air Command, Langley Air Force Base, Virginia
Commanding General, Tactical Air Force (Provisional), Pope Air Force Base, North Carolina
Commanding General, First Air Force, Mitchel Air Force Base, New York
Commanding General, Fourth Air Force, Hamilton Air Force Base, Hamilton, California
Commanding General, Ninth Air Force, Langley Air Force Base, Virginia
Commanding General, Fourteenth Air Force, Robins Air Force Base, Georgia

The following amendments are made to Headquarters, Continental Air Command "Directive for the Implementation of Joint Army - Air Force Exercise, Fiscal Year 1950 - Swarmer," 7 February 1950, as amended.

* * * * * * * *

3. Task Organization.

a. * * * * * *

Add

(19) 52nd Fighter Group 8 aircraft

4. Tasks and Responsibilities.

* * * * * * * *

Add

g. First Air Force will:

(1) Train, equip, and make available on request of Commanding General, Tactical Air Force, required elements of those First Air Force units assigned to this exercise (paragraph 3, above).

(2) Furnish Commanding General, Tactical Air Force, for submission of movement requests to Headquarters, Continental Air Command, necessary information concerning participating First Air Force units.

Incl #3

0212

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(3) Submit detailed budget estimates and justification to Headquarters, Continental Air Command, for First Air Force units participating in the exercise. [illegible]

[illegible signature]

[illegible] B. T[illegible]
Brig General, [illegible]
D[illegible] for Operations

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CG, Ninth Air Force	1 cys
CG, Fourteenth Air Force	1 cys
[illegible] Command, [illegible]	1[illegible] cys
[illegible]	[illegible] cys
Air University	5 cys
Air Materiel Command	1[illegible] cys
[illegible] Fighter-Bomber Wing	[illegible] cys
4th Fighter - Interceptor Wing	1[illegible] cys
[illegible] Troop Carrier Wing	[illegible] cys
[illegible] Troop Carrier Wing	5 cys
[illegible] Tactical Reconnaissance [illegible]	[illegible] cys
[illegible] Tactical Reconnaissance Squadron	2 cys
[illegible] Tactical Control Group	[illegible] cys
[illegible] Signal Battalion	2 cys
[illegible] Weather Unit	2 cys
CG, [illegible] (Provisional)	1[illegible] cys
CG, First Air Force	1[illegible] cys
33rd Fighter Wing	5 cys
Eastern Air Defense Force	[illegible] cys
Western Air Defense Force	[illegible] cys
[illegible] Fighter Wing	[illegible] cys
5[illegible] Fighter Wing	[illegible] cys

0213

HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK

4 April 1950

SUBJECT: Amendment to Directive for the Implementation of Joint Army-Air Force Exercise, Fiscal Year 1950 - "Swarmer"

TO: Commanding General, Tactical Air Command, Langley Air Force Base, Virginia
Commanding General, Tactical Air Force (Provisional), Pope Air Force Base, North Carolina
Commanding General, First Air Force, Mitchel Air Force Base, New York
Commanding General, Fourth Air Force, Hamilton Air Force Base, Hamilton, California
Commanding General, Ninth Air Force, Langley Air Force Base, Virginia
Commanding General, Fourteenth Air Force, Robins Air Force Base, Georgia

The following amendments are made to Headquarters, Continental Air Command, "Directive for the Implementation of Joint Army-Air Force Exercise, Fiscal Year 1950 - "Swarmer", 7 February 1950, as amended.

* * * * * * *

3. Task Organization

a. * * * * *

Add

(17) 2nd Liaison Flight 1 Flt

(18) 3rd Liaison Flight 1 Flt

* * * * * * *

/s/ E. Mackinnon Col
for HERBERT B. THATCHER
Brig. General, USAF
Deputy for Operations

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MATS	5 cys
Air University	5 cys

Incl #4

0214

Amendment to Directive for the Implementation of Joint Army - Air Force Exercise, Fiscal Year 1950 - "Swarmer" (Contd)

<u>DISTRIBUTION</u> (Contd)

Air Material Command	10 cys
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4th Fighter - Interceptor Wing	12 cys
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62nd Troop Carrier Wing	5 cys
161st Tactical Reconnaissance Squadron	2 cys
162nd Tactical Reconnaissance Squadron	2 cys
502nd Tactical Control Group	4 cys
934th Signal Battalion	2 cys
Shoran Beacon Unit	2 cys
CG, TAF (Provisional)	15 cys
CG, First Air Force	10 cys
33rd Fighter Wing	5 cys

(ED)

HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK

20 April 1950

SUBJECT: Amendment to Directive for the Implementation of Joint Army-Air Force Exercise, Fiscal Year 1950 - "Swarmer"

TO: Commanding General, Tactical Air Command, Langley Air Force Base, Virginia
Commanding General, Tactical Air Force (Provisional), Pope Air Force Base, North Carolina
Commanding General, First Air Force, Mitchel Air Force Base, New York
Commanding General, Fourth Air Force, Hamilton Air Force Base, Hamilton, California
Commanding General, Ninth Air Force, Langley Air Force Base, Virginia
Commanding General, Fourteenth Air Force, Robins Air Force Base, Georgia

The following amendments are made to Headquarters, Continental Air Command, "Directive for the Implementation of Joint Army-Air Force Exercise, Fiscal Year 1950 - "Swarmer", 7 February 1950, as amended.

*   *   *   *   *   *   *

4. Tasks and Responsibilities.

Add the following paragraph to d, e, f, and g.

Submit to Headquarters, Continental Air Command, no later than 5 June 1950, the total flying hours expended by unit and type aircraft on following phases of the exercise:

(1) Pre-maneuver (Prior to D-Day)

(2) Maneuver (D-Day to End of Maneuver)

(3) Post Maneuver (End of maneuver to arrival at home base).

HERBERT B. THATCHER
Brig. General, USAF
Deputy for Operations

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Incl #5

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Amendment to Directive for the Implementation of Joint Army - Air Force Exercise, Fiscal Year 1950 - "Swarmer" (Contd)

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CG, Fourteenth Air Force	15 cys
Maneuver Commander, Exercise Swarmer	10 cys
MATS	5 cys
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Air Materiel Command	10 cys
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62nd Troop Carrier Wing	5 cys
161st Tactical Reconnaissance Squadron	2 cys
162nd Tactical Reconnaissance Squadron	2 cys
502nd Tactical Control Group	4 cys
934th Signal Battalion	2 cys
Shoran Beacon Unit	2 cys
CG, TAF (Provisional)	15 cys
CG, First Air Force	10 cys
33rd Fighter Wing	5 cys
78th Fighter Wing	5 cys
Eastern Air Defense Force	5 cys
Western Air Defense Force	5 cys
52nd Fighter Wing	5 cys

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HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK

17 March 1950

SUBJECT: Amendment to Directive for the Implementation of Joint Army - Air Force Exercise, Fiscal Year 1950 - "Swarmer"

TO: Commanding General, Tactical Air Command, Langley Air Force Base, Virginia
Commanding General, Tactical Air Force (Provisional), Pope Air Force Base, North Carolina
Commanding General, First Air Force, Mitchel Air Force Base, New York
Commanding General, Fourth Air Force, Hamilton Air Force Base, Hamilton, California
Commanding General, Ninth Air Force, Langley Air Force Base, Virginia
Commanding General, Fourteenth Air Force, Robins Air Force Base, Georgia

The following amendments are made to Headquarters, Continental Air Command "Directive for the Implementation of Joint Army - Air Force Exercise, Fiscal Year 1950 - "Swarmer", 7 February 1950, as amended.

* * * * * *

3. Task Organization.

a. * * * * *

(4) Delete 33rd Fighter - Interceptor Group - 1 Sq. (F-84)

and replace with

78th Fighter - Interceptor Group - 1 Sq. (Red)

* * * * * *

4. Tasks and Responsibilities.

a. * * * * *

(3) Provide necessary augmentation for Tactical Air Force Headquarters (Provisional) based on requests submitted by Commanding General, Fourteenth Air Force. Requests will be coordinated with Commanding General, Tactical Air Force by Commanding General, Fourteenth Air Force, prior to submission to Headquarters, Continental Air Command.

* * * * * * *

Incl # 4

0218

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Directive for the Implementation of Joint Army-Air Force Exercise, Fiscal Year 1950 - "Swarmer" (Contd)

b. * * * * *

c. * * * * *

(3) Forward requests for augmentation of Tactical Air Force (Provisional) to Headquarters, Fourteenth Air Force, for this exercise. (Requests to include rank, MOS, and reporting date.)

* * * * * *

d. * * * * *

e. * * * * *

f. * * * * *

g. Delete.

* * * * * *

HERBERT B. THATCHER
Brig. General, USAF
Deputy for Operations

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20th Fighter-Bomber Wing	8 cys
4th Fighter - Interceptor Wing	12 cys
314th Troop Carrier Wing	12 cys
62nd Troop Carrier Wing	5 cys
161st Tactical Reconnaissance Squadron	2 cys
162nd Tactical Reconnaissance Squadron	2 cys
502nd Tactical Control Group	4 cys
934th Signal Battalion	2 cys
Shoran Beacon Unit	2 cys
CG, TAF (Provisional)	15 cys
CG, First Air Force	10 cys
33rd Fighter Wing	5 cys
78th Fighter Wing	5 cys
EADF	5 cys
WADF	5 cys

SWARMER

Department of the Army | Department of the Air Force

Washington 25, D. C. 14 March 1950

AMENDMENTS

To Directive for Joint (Army-Air Force) Exercise, FY 1950

1. Amend paragraph 4, to read as follows:

* *) * *

4. Participating forces:

a. Maneuver Commander is assigned the following troops and units to implement the concept stated in paragraph 3:

(1) Army:
Corps headquarters
2 Airborne divisions
1 Infantry division hq (CPX)
1 Infantry RCT
AGGRESSOR CHQ units, Ft Riley, Kansas
Necessary combat and service support.

(2) Air Force:
Tactical Air Force (Prov)
7 Troop carrier squadrons
Additional transport aircraft as required
4 Fighter groups minus 2 squadrons
2 Light bomb squadrons
2 Tactical reconnaissance squadrons
Elements of tactical control group
Elements of Signal battalion
1 Liaison flight
Detachment SHORAN beacon unit
1 Reconnaissance technical squadron
AACS and AWS support as required by Maneuver Commander.

All Air Force units listed above organized on wing base plan will furnish necessary supporting units for combat groups.

Incl #2

0220

b. Reserve components -- no change.

c. Maneuver Commander will publish general plan indicating use of assigned forces and plan of maneuver.

* * * * *

2. Delete Inclosure 1 to directive.

BY ORDER OF THE SECRETARIES OF THE ARMY AND AIR FORCE:

S. E. ANDERSON
Major General, USAF
Director, Plans and Operations

CHARLES L. BOLTE
Major General, GSC
ACofS, G-3

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0221

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HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK

7 March 1950

SUBJECT: Amendment to Directive for the Implementation of Joint Army - Air Force Exercise, Fiscal Year 1950 - "Swarmer"

TO: Commanding General, Tactical Air Command, Langley Air Force Base, Virginia
Commanding General, Tactical Air Force (Provisional), Pope Air Force Base, North Carolina
Commanding General, First Air Force, Mitchel Air Force Base, New York
Commanding General, Fourth Air Force, Hamilton Air Force Base, Hamilton, California
Commanding General, Ninth Air Force, Langley Air Force Base, Virginia
Commanding General, Fourteenth Air Force, Robins Air Force Base, Georgia

The following amendments are made to Headquarters, Continental Air Command "Directive for the Implementation of Joint Army - Air Force Exercise, Fiscal Year 1950 - Swarmer," 7 February 1950.

* * * * * * *

Delete paragraph 3 "Task Organization" and rewrite as follows:

3. Task Organization.

a. Necessary elements of the following units are hereby committed to this exercise.

(1)	20th Fighter - Bomber Group	3 Squadrons
(2)	4th Fighter - Interceptor Group	3 Squadrons
(3)	31st Fighter - Bomber Group	3 Squadrons
(4)	33rd Fighter - Interceptor Group	1 Squadron (F-84)
(5)	314th Troop Carrier Group	3 Squadrons
(6)	316th Troop Carrier Group	3 Squadrons
(7)	62nd Troop Carrier Group	1 Squadron
(8)	84th Bomb Squadron (Light)	1 Squadron
(9)	85th Bomb Squadron (Light)	1 Squadron
(10)	161st Tactical Reconnaissance Sq	1 Squadron
(11)	162nd Tactical Reconnaissance Sq	1 Squadron
(12)	502nd Tactical Control Group	2 Detachments

Incl #3

Amendment to Directive for the Implementation of Joint Army - Air Force - Exercise, Fiscal Year 1950 - "Swarmer" (Contd)

(13)	934th Signal Battalion	1 Detachment
(14)	4th Liaison Flight	1 Flight
(15)	Shoran Beacon Unit	1 Detachment
(16)	363 Reconnaissance Technical Sq	1 Squadron

All units listed above organized on Wing Plan will furnish necessary supporting units for combat group.

b. Reserve Component - Employment of Air National Guard and Air Reserve units and personnel is authorized. Maneuver Commanders requirements will be coordinated by Commanding General, Continental Air Command.

4. Tasks and Responsibilities.

* * * * * * *

Add

g. First Air Force will:

(1) Train, equip, and make available on request of Commanding General, Tactical Air Force, required elements of those First Air Force units assigned to this exercise (paragraph 3, above).

(2) Furnish Commanding General, Tactical Air Force, for submission of movement requests to Headquarters, Continental Air Command, necessary information concerning participating First Air Force units.

(3) Submit detailed budget estimate and justification to Headquarters, Continental Air Command, for First Air Force units participating in the maneuver.

* * * * * * *

HERBERT B. THATCHER
Brig. General, USAF
Deputy for Operations

Amendment to Directive for the Implementation of Joint Army - Air Force Exercise, Fiscal Year 1950 - "Swarmer" (Contd)

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62nd Troop Carrier Wing	5 cys
161st Tactical Reconnaissance Squadron	2 cys
162nd Tactical Reconnaissance Squadron	2 cys
502nd Tactical Control Group	4 cys
9 4th Signal Battalion	2 cys
Shoran Beacon Unit	2 cys
CG, TAF (Provisional)	2 cys
CG, First Air Force	15 cys
33rd Fighter Wing	10 cys
	5 cys

0224

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HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK

7 February 1950

SUBJECT: Directive for the Implementation of Joint Army-Air Force Exercise, Fiscal Year 1950 - "Swarmer"

TO : Commanding General, Tactical Air Command, Langley Air Force Base, Virginia
Commanding General, Tactical Air Force (Provisional), Pope Air Force Base, North Carolina
Commanding General, Fourth Air Force, Hamilton Air Force Base, Hamilton, California
Commanding General, Ninth Air Force, Langley Air Force Base, Virginia
Commanding General, Fourteenth Air Force, Robins Air Force Base, Georgia

1. Attached for your information and necessary action is a copy of Headquarters, Continental Air Command Directive for the Implementation of Joint Army-Air Force Exercise, Fiscal Year 1950 - "Swarmer", 7 February 1950.

2. This directive is subject to change since an increase in size and scope of the maneuver has been indicated by the Maneuver Commanders Staff. Your headquarters will be advised of these changes upon their approval by this and higher headquarters.

BY COMMAND OF LIEUTENANT GENERAL WHITEHEAD:

[illegible] R. [illegible]
Brig. General, USAF
Deputy for Operations

1 Incl:
1. Directive for the Implementation of Jt Army-AF Exercise, FY 1950-"SWARMER" w/incl

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162nd Tactical Reconnaissance Squadron	2 cys
502nd Tactical Control Group	4 cys
934th Signal Battalion	2 cys
Shoran Beacon Unit	2 cys

Inclosure #1

3-14-8

0225

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HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK

DIRECTIVE FOR THE IMPLEMENTATION
of
of JOINT ARMY-AIR FORCE EXERCISE,

FISCAL YEAR 1950 - "SWARMER"

HQ CONAC
7 February 1950

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HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK

7 February 1950

SUBJECT: Directive for the Implementation of Joint Army-Air Force Exercise, Fiscal Year 1950 - "Swarmer"

TO : Commanding General, Tactical Air Command, Langley Air Force Base, Virginia
Commanding General, Tactical Air Force (Provisional), Pope Air Force Base, North Carolina
Commanding General, Fourth Air Force, Hamilton Air Force Base, Hamilton, California
Commanding General, Ninth Air Force, Langley Air Force Base, Virginia
Commanding General, Fourteenth Air Force, Robins Air Force Base, Georgia

1. The Chiefs of Staff, United States Army and United States Air Force, have directed that a joint exercise, employing units of the Army and Air Force, be conducted in the Third Army and Fourteenth Air Force area, in April - May 1950.

2. Attached hereto is a copy of the directive from the Chiefs of Staff, United States Army and United States Air Force, for the implementation of the joint exercise, which outlines the purpose, concept, procedures, and responsibilities of the respective services. (Inclosure #1)

3. Task Organization.

Necessary elements of the following units are hereby committed to this exercise.

a.	20th Fighter-Bomber Wing	3 Squadrons
b.	4th Fighter-Interceptor Wing	3 Squadrons (Fighter)
		2 Squadrons (Lt Bomb)
c.	314th Troop Carrier Wing	6 T C Squadrons
d.	62nd Troop Carrier Wing	1 T C Squadron
e.	161st Tactical Reconnaissance Sq	1 Squadron
f.	162nd Tactical Reconnaissance Sq	1 Squadron
g.	502nd Tactical Control Group	2 Detachments
h.	934th Signal Battalion	1 Detachment
i.	Shoran Beacon Unit	1 Detachment
j.	4th Liaison Flight	1 Flight

Directive for the Implementation of Joint Army-Air Force Exercise, Fiscal Year 1955 - "Swarmer" (Contd)

3. Reserve components - Employment of ANG and Air Reserve units and personnel is authorized. Maneuver Commanders requirements will be coordinated by Commanding General, Continental Air Command.

4. Tasks and Responsibilities.

a. Continental Air Command will:

(1) Designate the Deputy Chief Umpire.

(2) Coordinate the Maneuver Commanders requirements for ANG and Air Reserve units.

(3) Provide necessary augmentation for Tactical Air Force Headquarters (Provisional), based on requests submitted by Commanding General, Tactical Air Force (Provisional).

(4) Process fuel and ordnance requisitions as requested.

(5) Monitor entire operation and provide all other assistance within scope of funds available.

b. Tactical Air Command will:

(1) Monitor Air Force activities during the exercise to insure compliance with existing doctrine and procedures, and render all assistance possible to the Maneuver Commander and Tactical Air Force (Provisional).

c. Tactical Air Force (Provisional) will:

(1) Be responsible for tactical employment of Air Force units assigned this exercise.

(2) Be responsible for the operation of the Air Force Combat Operations Section of the Joint Operations Center, and supervision of the Tactical Control System.

(3) Forward requests for augmentation of Tactical Air Force (Provisional) to Headquarters Continental Air Command for this exercise. (Requests to include rank, MOS, and reporting date)

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(4) Make available to Fourteenth Air Force necessary information for prompt submission of budget estimate and justification.

(5) Determine exact requirements and troop list of units allocated to this exercise in paragraph 3, above.

(6) Forward to Headquarters, Continental Air Command, copies of all orders and instructions issued to subordinate units.

(7) Prepare and publish the Air Operation Plan for the conduct of this exercise and issue necessary implementing orders and instructions to all participating Air Force units.

(8) Submit requests for movement of all Air Force units, to Headquarters, Continental Air Command, in accordance with paragraph 11, Air Force Regulation 75-20 immediately upon receipt of this directive.

(9) Issue movement orders for all Air Force units upon receipt of authority from Headquarters, Continental Air Command.

(10) Establish immediate liaison and conduct concurrent planning with appropriate agencies.

d. Fourth Air Force will:

(1) Train, equip, and make available on request of Commanding General, Tactical Air Force, required elements of those Fourth Air Force units assigned to this exercise (paragraph 3, above).

(2) Furnish Commanding General, Tactical Air Force, for submission of movement requests to Headquarters, Continental Air Command, necessary information concerning participating Fourth Air Force units.

Directive for the Implementation of Joint Army-Air Force Exercise, Fiscal Fiscal Year 1950 - "Swarmer" (Contd)

(3) Submit detailed budget estimate and justification to Headquarters, Continental Air Command, for Fourth Air Force units participating in the maneuver.

e. Ninth Air Force will:

(1) Train, equip, and make available on request of Commanding General, Tactical Air Force, required elements of those Ninth Air Force units assigned to this exercise (paragraph 8, above).

(2) Furnish Commanding General, Tactical Air Force, for submission of movement requests to Headquarters, Continental Air Command, necessary information concerning participating Ninth Air Force units.

(3) Submit detailed budget estimate and justification to Headquarters, Continental Air Command, for Ninth Air Force units participating in the maneuver.

f. Fourteenth Air Force will:

(1) Provide necessary logistical and administrative support within maneuver area for all Air Force units participating in this exercise.

(2) Prepare necessary logistics and administrative plans as requested by Commanding General, Tactical Air Force.

(3) Submit to Headquarters, Continental Air Command, logistics requirements which are beyond the capabilities of Fourteenth Air Force.

(4) Submit detailed budget estimate and justification to Headquarters, Continental Air Command, on Fourteenth Air Force units and Air Umpire Group.

(5) Train, equip, and make available, upon request of Commanding General, Tactical Air Force, required elements of those Fourteenth Air Force units assigned to this

Directive for the Implementation of Joint Army-Air Force Exercise, Fiscal Year 1950 - "Swarmer" (Contd)

exercise (paragraph 3, above).

(c) Furnish Commanding General, Tactical Air Force, for submission of movement requests to Headquarters, Continental Air Command, necessary information concerning participating Fourteenth Air Force units.

5. Direct communication is authorized between all addressees of this directive for planning purposes and execution of this exercise.

BY COMMAND OF LIEUTENANT GENERAL WHITEHEAD:

HERBERT B. THATCHER
Brig. General, USAF
Deputy for Operations

1 Incl:
1. Directive for Jt (Army-AF)Exer FY 1950, 10 Dec 49

RESTRICTED

"SWARMER"

DEPARTMENT OF THE ARMY DEPARTMENT OF THE AIR FORCE

Washington 25, D. C., 10 December 1949

Directive for Joint (Army-Air Force) Exercise, FY 1950

1. Directive A Joint Army - Air Force exercise involving airborne landings, ground and tactical air operations, will be held in the Third Army and Fourteenth Air Force area, in April - May 1950.

2. Purpose

a. To provide training and experience in the operation of a joint maneuver headquarters.

b. To study the organization and operation of an airhead.

c. To develop aerial resupply procedures and techniques.

d. To train Army and Air Force units and staffs in the procedure, tactics, and techniques incident to air-ground and airborne operations.

e. To test and evaluate methods of close air support for airborne units.

f. To determine requirements for special equipment which may be substituted for equipment in the land tail of airborne units.

g. To test tactical application of new developments in weapons.

h. To evaluate training proficiency of participating units as a basis for prescribing further training for combat readiness.

3. Concept

a. That air attacks followed by an airborne landing by AGGRESSOR nation have created a state of war between AGGRESSOR and the United States.

b. That having gained local control of the air against the dispersed United States Air Force units, an airhead is established by AGGRESSOR in North Carolina.

c. That having concentrated air and ground forces under the command of the Commanding General, Tactical Air Force, and Commanding General, Third Army, the United States is able to cut off AGGRESSOR's supply line and check AGGRESSOR advance.

d. That a timely airborne operation by Joint United States Forces contributes to the eventual annihilation of AGGRESSOR forces in the airhead.

4. Participating Forces

a. United States Forces:

(1) Army: One airborne division and supporting units.

(2) Air Force: Seven Troop Carrier Squadrons.

(Same units used by AGGRESSOR)

One Fighter Group

Inclosure #1

RESTRICTED

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Two Light Bomb Squadrons

One Tactical Reconnaissance Squadron

Elements of Tactical Control Group

Elements of Signal Battalion

One (1) Liaison Flight

Detachment SHORAN Beacon Unit

b. AGGRESSOR Forces

(1) Army: One Airborne Division (less one RCT and less one BCT) with supporting units.

AGGRESSOR GHQ units, Fort Riley, Kansas

(2) Air Force: Seven Troop Carrier Squadrons

One Fighter Group

One Tactical Reconnaissance Squadron

Elements of Tactical Control Group

c. Reserve Components

Employment of National Guard and Organized Reserve Corps units and personnel is authorized. Maneuver Commander's requirements will be coordinated by Chief, Army Field Forces, and by Commanding General, Continental Air Command.

5. Command Structure (Appendix A)

a. The maneuver director will be designated by the Chief of Staff, United States Air Force.

b. AGGRESSOR forces will be controlled by the Maneuver Commander. Joint Tactical Air Force - Army organization in the AGGRESSOR headquarters will be simulated. The Joint Operations Center will be the only element of the AGGRESSOR headquarters which will actively operate.

c. Unilateral components of the United States maneuver forces will be designated by respective services. The Maneuver Commander is authorized to prescribe the formation of a joint United States maneuver force or a joint AGGRESSOR Force and designate Commander thereof.

d. Chief, Army Field Forces, will designate the Chief Umpire for the Exercise. Commanding General, Continental Air Command, will designate the Deputy Chief Umpire.

6. Joint Maneuver Staff

a. The United States Air Force will provide personnel for the joint maneuver staff, to be organized as prescribed by Maneuver Commander.

b. Chief, Army Field Forces, will issue necessary orders to Army Commanders for provision of Army personnel required for the joint maneuver staff as prescribed by Maneuver Commander.

7. Responsibilities

a. Maneuver Commander is responsible for the overall conduct and planning of the exercise. His activities will include:

(1) Establishment, supervision, and training of umpire group.

(2) Establishment and supervision of Public Relations Bureau.

(3) Establishment and supervision of Visitors' Bureau.

(4) Tactical employment of AGGRESSOR forces.

b. Chief, Army Field Forces, is responsible for implementation of Department of the Army participation in the exercise.

c. Commanding General, Third Army (under coordination and supervision of Chief, Army Field Forces) will be responsible for:

(1) Provision of necessary housing and facilities for the joint maneuver headquarters.

(2) Administrative and logistical support of the Army maneuver forces and umpire group.

(3) Procurement and distribution of maps for all participating Army units.

(4) Provision of personnel for the Air-ground operations section of the United States Forces Joint Operations Center.

(5) Administration of special field exercises funds for the Army elements of the exercise.

d. Commanding General, Continental Air Command, will be responsible for:

(1) Provision of Air Force units outlined in paragraph 4.

(2) Designation of agencies responsible for the logistical and administrative support of participating Air Force units and umpire group.

(3) Designation of agencies responsible for submission of requirements for Air Combat Maneuver Funds and umpire group.

(4) Designation of agencies responsible for the production of the Air Operation Plan.

e. Commanding General, Tactical Air Force, will be responsible for:

(1) Tactical employment of maneuver United States Air Force units.

(2) Operation of the United States Forces Combat Operations Section of the Joint Operations Center, and supervision

of the Tactical Control System.

8. Intelligence

During preliminary planning stages, this exercise will be classified as restricted. As soon as necessary movement instructions have been issued to units, and on instructions of Maneuver Commander, security classification will be eliminated. For the play of the exercise intelligence problems will be incorporated in all phases. AGGRESSOR will be used to develop the enemy situation so that United States forces intelligence agencies may simulate operational conditions.

9. Communication

a. Maneuver Commander is authorized to call upon participating units for such personnel as may be required in the conduct of his activity.

b. Direct communication is authorized among the major commanders and the Chief, Army Field Forces, indicated herein.

10. Reports

Maneuver Commander will prepare reports covering the exercise, limited to essential facts.

BY ORDER OF THE SECRETARIES OF THE AIR FORCE AND ARMY:

/s/ S. E. Anderson
/t/ S. E. ANDERSON
Major General, U. S. Air Force
Director of Plans and Operations.

/s/ Clift Andrus
/t/ CLIFT ANDRUS
Major General, U. S. Army
Director of Organization & Training

1 Incl
Appendix A

Distribution:

Chief of Staff, U.S. Air Force - 150 copies
Chief of Staff, U.S. Air Force,
for Maneuver Commander - 150 copies.
Chief of Staff, U.S. Army - 150 copies

RESTRICTED

SWARMER

Maneuver Commander
(USAF)

Deputy and Chief of Staff
(Army)

Joint Staff

J-1 PA J-2 Intel J-3 Opns J-4 Logs J-5 Com

Joint Umpire Group

UNITED STATES FORCES

Air Command JOC
(Tactical Air Force)

*TC Sqs
Ftr Groups
Lt Bmb Sqs
Tac Rcn Sqs
Liaison Flight
Detachment SHORAN Beacon Unit

Army Command
(V Corps)

82d Abn Div (reinf)
**Elms 3d Inf Div
Elms Natl Guard
AA Bnd
Armors

*Also support AGG [illegible]

**Air Transported

AGGRESSOR FORCES

Army Command JOC

11th Abn Div (-)

Air Command

TC Sqs
Ftr Sqs
Rcn Sqs

Appendix A

Inclosure No. 1.

RESTRICTED

AIR UMPIRE MANUAL

FOR

SWARMER

A JOINT
ARMY-AIR FORCE-NAVY
EXERCISE

NORTH CAROLINA – SOUTH CAROLINA

APRIL 1950 MAY

AIR UMPIRE SECTION, SWARMER
Fort Bragg, North Carolina

TABLE OF CONTENTS

8-3391-6

AIR UMPIRE SECTION (SWARMER)
Fort Bragg, North Carolina

7 March 1950

FOREWORD

This manual will provide Air Umpires with pertinent Umpire rules and Damage Assessment Tables for easy reference.

These rules and instructions are provided as a standard and should not be dogmatically invoked when common sense and good judgement dictate the necessity for deviation, provided the spirit of the written directive is not violated.

The safety of participating personnel should be considered when invoking decisions contrary to published criteria.

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SYNOPSIS OF EXERCISE SWARMER

1. GENERAL

a. Exercise Swarmer is a joint Army-Air Force-Navy maneuver being held in the Camp MacKall-Fort Bragg area during the period 24 April to 8 May. It is planned to include the tactical air movement of an estimated 18,000 Army Airborne troops. It is, in the main, a controlled maneuver, control being exercised through an umpire organization, which also operates to maintain realistic combat situations. There is to be a minimum of assumed forces in the maneuver area proper.

b. The primary purpose of this maneuver is the study of problems involved in the establishment and maintenance of an airhead in the face of air and ground opposition; particularly, the capability of the USAF to defend troop and supply movements and necessary airfields from air attack and to also provide close support to the airborne troops in their ground battle.

c. Secondary purposes are:

(1) To provide training and experience in the operation of a joint headquarters.

(2) To develop procedures and techniques of aerial resupply.

(3) To train Army and Air Force units and staffs in the procedures, tactics, and techniques incident to Air-Ground and Airborne operations.

(4) To test and evaluate methods of close air support for Airborne units.

(5) To determine requirements for special equipment that may be substituted for the heavy non-air-transportable equipment in the "by-land" tail of airborne units.

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(6) To test tactical application of new developments in weapons.

(7) To evaluate training proficiency of participating units as a basis for prescribing further training for combat readiness.

2. SITUATION

a. General: A state of war exists between AGGRESSOR nation and the United States caused by invasions of the United States. AGGRESSOR, taking advantage of the normally scattered U. S. Armed Forces, has seized the Florida peninsula, and has invaded North Carolina by amphibious and airborne operations, generally from the coast in the Wilmington area; he is capable of an added invasion either into Georgia, or from the eastern Gulf. Third Army and Tactical Air Force have concentrated forces to operate against the invader in the North Carolina area.

b. Special: U. S. Forces plan to establish an airhead within the invaded area, in the vicinity of Fort Bragg, for the purpose of cutting AGGRESSOR supply lines, stopping his advance to the north and west, and destroying the main elements of the AGGRESSOR forces. U. S. Forces from west of the Great Smoky Mts., are to seize the small, lightly defended, Camp MacKall airfield as a first air supply point, and drop airborne troops in three areas of the Fort Bragg reservation. Pope Air Force Base is the second objective of these ground troops, in order to gain a fully developed airdrome for air landing of additional troops, equipment and supplies. A third objective is the capture of the Fayetteville Airport (assumed, just south of the Reservation) that is being used as a supply point, by airlift, for

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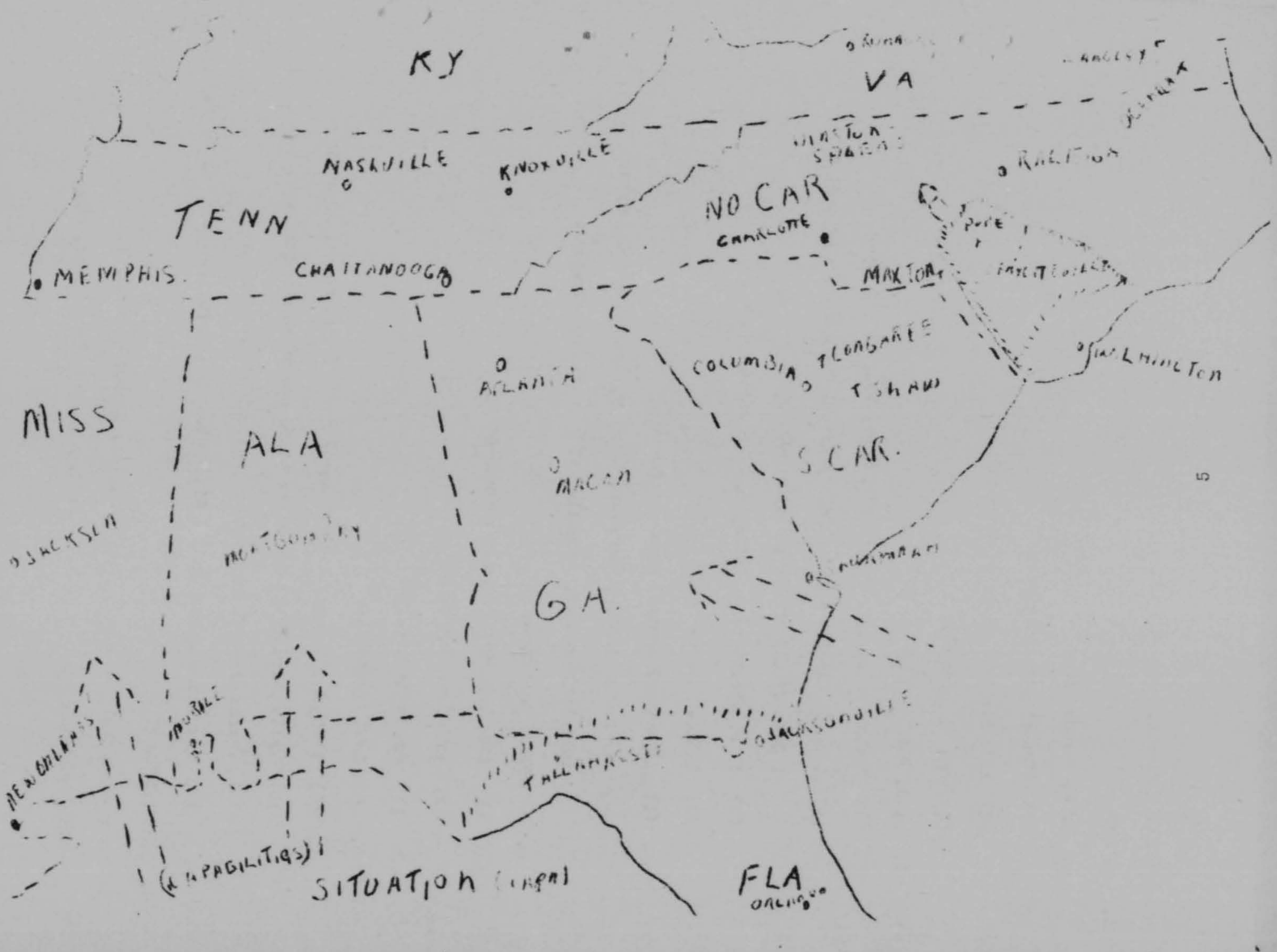

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the AGGRESSOR Forces.

3. TROOPS

a. U. S. Forces, Army

(1) 82nd Airborne Division

(2) 11th Airborne Division (reduced)

(3) One Liaison flight

b. U. S. Forces, Air

(1) 3 Fighter Groups: 4th: F86, 20th: F84, USMC: 2 Sqdns

(2) 3 Troop carrier Gps: 7 Squadrons: 1 Sqdn of 62d: C54, 314th: 1 Sqdn C82, 2 of C119, 316th: C82

(3) 1 Transport Group: MATS, 4 of 5 Sqdns: C54

(4) 1 Tac. Recon. Sqdn

(5) 1 Tactical Control Group (reduced)

(6) Air Bases at Shaw, Congaree, Langley, Oceana, and Charlotte (the last assumed, actually using Laurinburg-Maxton).

c. AGGRESSOR Forces, Army

(1) 15th Infantry, heavily reinforced

(2) 44th Tank Battalion

(3) One Liaison flight

d. AGGRESSOR Forces, Air

(1) 1 Fighter Group, 31st: 3 Sqdns F84, 1 Tac. Recon. Squadron

(2) Troop Carrier and Transport minor use of same units as U. S.

(3) Forces above Elements of a Tactical Control Group.

(4) Air Base assumed in the Wilmington area, actually using Langley.

4. KEY PERSONNEL

Maneuver Commander	Lt. Gen. Lauris Norstad, USAF
Chief of Staff	Brig. Gen. Ridgely Gaither, Army

J-1, Personnel	Col. H. R. Rogers, USAF
J-2, Intelligence	Lt Col. M. D. Heasley, Army
J-3, Operations	Col. F. H. Hears, USAF
J-4, Logistics	Lt. Col. A. L. Sanford, Army
J-5, Communications	Col. B. H. Wooton, USAF
Hq. Commandant	Col. H. C. Shea, Army
C.G., U. S. Forces	Maneuver Commander
C.G., U. S. Forces, Army	Lt Gen. John R. Hodge, Army (C. G., V Corps and Fort Bragg)
C.G., U. S. Forces, Air	Brig. Gen. W. Wolfinbarger, USAF
C.G., AGGRESSOR Forces	Maj. Gen. Robert M. Lee, USAF
C.O., AGGRESSOR Forces, Army	Col. D. M. Moore, Army
C.O., AGGRESSOR Forces, Air	C. O., 31st Fighter Wing
Chief Umpire	Brig. Gen. G. J. Higgins, Army
Deputy	Col. R. T. Cronau, USAF
Executive	Col. J. D. Scott, Army
Chief Ground Umpire	Col. J. R. Jeter, Army
Chief Air Umpire	Col. H. T. McCormick, USAF
U. S. Forces Air Umpire	Col. L. P. Turner, USAF
AGGRESSOR Air Umpire	Col. B. B. Harper, USAF

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AIR UMPIRE SECTION (SWARMER)
Fort Bragg, North Carolina

Operations Plan
CAU. No 1-50

15 February 1950

1. Maps: a. Sectional Aeronautical Charts.

(RS-9) Norfolk
(Q-8) Savannah
(S-8) Winston Salem
(R-8) Charlotte

b. Strategic Map W/D
Scale 1-50,000 Charlotte

c. Ft Bragg Topographic Sheet C/E
Scale 1-50,000

d. Army Map Service Topographic Sheet
12 sheets covering maneuver area
Scale 1-25,000

e. Army Map Service
Sheet 8301
Scale 1-1,000,000

2. References:

a. Department of the Army and department of the Air Force directive for joint (Army and Air Force) Exercise Fy 1950

b. Letter Hqrs Maneuver Commander, Exercise Swarmer, Subject General plan for training "Exercise Swarmer" dated 6 Feb 1950

c. Command Memorandum, Hqrs Umpire Group "Exercise Swarmer" dated 24 Feb 1950, subject Duties and responsibilities of Chief Air Umpire, Exercise Swarmer

3. Task Organization:

a. Chief Air Umpire — Col Harlan T. McCormick — USAF

b. D/CAU Operations — Col Don W. Mayhue — USAF

Chief Umpire, U.S. Forces, Air (Swarmer)
Col L. P. Turner — USAF

Chief Umpire Aggressor Forces, Air(Defense)
Col B. B. Harper — USAF

c. D/CAU Personnel — Lt Col R. G. Boyd — USAF

d. D/CAU Communications — Lt Col M. S. Brooks — USAF

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c. D/CAU Material — Lt Col A. Hanson — USAF

4. Information:

a. Department of the Army and Department of the Air Force Joint (Army - Air Force) Exercise Fy 1950 dated 10 December 1948 directed that a joint exercise be conducted in the Third Army and Fourteenth Air Force area in April - May 1950. The purpose of the exercise is:

(1) To provide training and experience in the operation of a maneuver Headquarters.

(2) To study the organization and operation of an airhead.

(3) To develop aerial resupply procedures and techniques.

(4) To train Army and Air Force Units and Staffs in the procedure tactics, and techniques incident to air-ground and airborne operations.

(5) To test and evaluate methods of close Air support for Airborne units.

(6) To determine requirements for special equipment which may be substituted for equipment in the land tail of airborne units.

(7) To test tactical application of new developments in weapons.

(8) To evaluate training proficiency of participating units as a basis for prescribing further training for combat readiness.

b. The Chief Umpire was appointed by the Maneuver Commander Per Ltr Order No 122 Headquarters Sixth Army, Dated 16 Jan 50. Umpires for ground and Air were subsequently appointed by the department of the Army and Air Force.

c. This operation plan is based upon Chief Umpire Command Memorandum, dated 24 Feb 1950 and covers the operations of the Air Umpire Group in connection with Joint Exercise (Swarmer).

d. Enemy forces: None

e. Friendly forces: None

f. For details of forces to be umpired and observed see, Par 3b(4) GENERAL PLAN FOR TRAINING EXERCISE SWARMER.

5. Mission: The Air Umpire Group will;

a. Procure Personnel and equipment for the group.

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b. Organize and train the group.

c. Administer the group.

d. Prepare Air Umpire Rules and instructions for all Air Operations.

(1) Air Umpire rules to be guided by FM 105-5, FM 30-101, FM 30-103, FM 30-102, FM 31-35, FM 71-30 USF 79A, USF 79(A)-1

(2) Air Umpire rules to be completed by 10 March 1950.

e. Umpire Invasion and Aggressor Force air elements during all phases.

(1) Umpire Air Planning.

(2) Umpire establishment and functioning of Air Force elements at all bases used in the maneuver.

(3) Umpire Air Operations and action.

(4) Pay particular attention to preparation, movement, control, coordination, and protection of airborne and troop carrier elements.

f. Reporting and Assignment Dates for Umpires.

(1) All Air Umpires will report to Ft Bragg, North Carolina for training not later than 25 March 1950.

(2) All Air Umpires will be in place with units to be umpired not later than 10 April 1950.

g. Upon completion of the exercise submit a report of Air Umpire activities in sufficient detail to permit the Chief Umpire to evaluate performance of all Air elements.

h. Execute other functions as directed.

6. Tasks:

a. D/CAU operations will:

(1) Assemble and coordinate the rules and regulations under which SAUS operates.

(2) Direct the planning, training and operational activities of all Air Umpires.

(3) Conceive, prepare, and monitor the operational and intelligence requirements for the Air Umpires Manual for all air elements.

b. DCAU Personnel will:

(1) Perform personnel and administration duties (to include adjutant functions) for Headquarters SAUS.

(2) Conceive, prepare, and monitor the personnel and administration requirements for the Air Umpire Manual.

c. DCAU/Communications will:

(1) Establish and maintain communication facilities for SAUS.

(2) Conceive, prepare, and monitor the communications requirements for the Air Umpire Manual.

d. DCAU Materiel will:

(1) Perform materiel function for SAUS to include individual Air Umpires during the training period.

(2) Conceive, prepare, and monitor the logistical requirements for the Air Umpire Manual.

7. Administration and Logistics: See Annexes C and D to this plan.

8. Command and Communications.

a. Communications in accordance with Air Umpire Communications plan, Annex B to this plan.

b. Chief Air Umpire will be located as follows:

(1) Headquarters SAUS, Fort Bragg North Carolina, 15 February 1950 - 10 April 1950.

(2) Headquarters SAUS, Camp McKall North Carolina, 10 April 1950 - 8 May 1950.

(3) Headquarters SAUS, Fort Bragg, North Carolina, 8 May 1950 - 15 May 1950.

HARLAN T McCORMICK
Col USAF
Chief Air Umpire

Annexes (to be published later)

Distribution:

Distribution List (Operations Plan, CAU No. 1-50)

ARMY

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CG 3rd Army	2
CG 4th Army	2
CG 5th Army	2
CG 6th Army	2
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11th Airborne Div	5
82nd Airborne Div	5
CG V Corps	5
C, AFF	5

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CNO	10

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C/S USAF	10
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AIR UMPIRE SECTION (SWARMER) (SAUS)
Fort Bragg, North Carolina

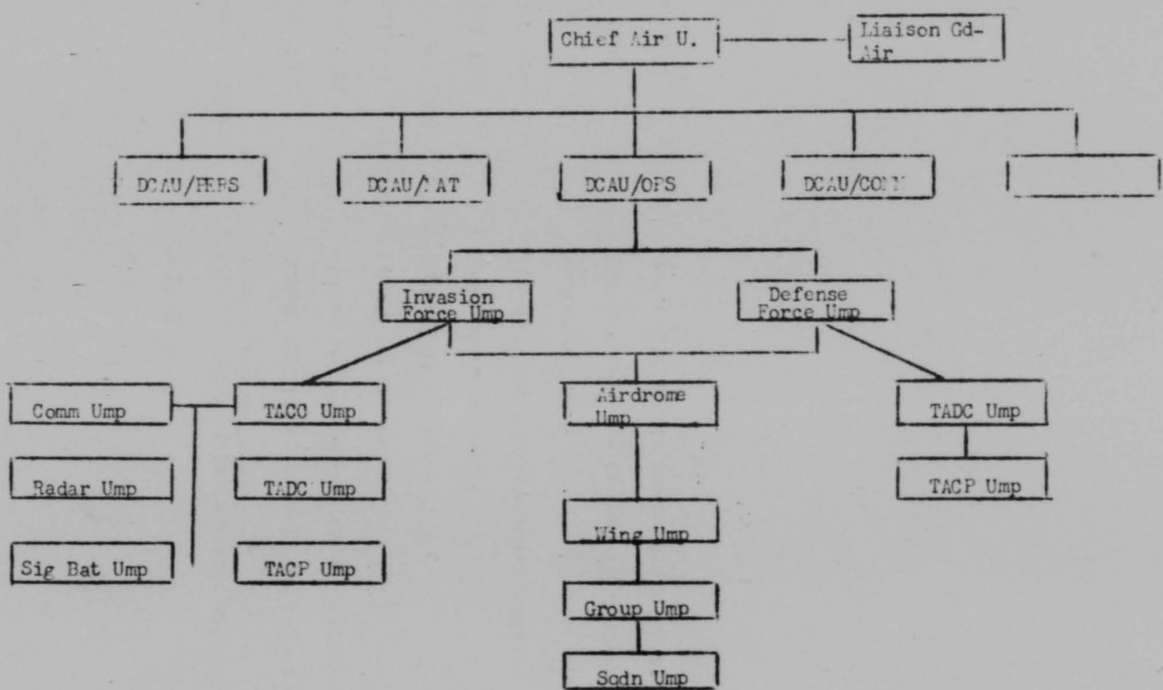
Inclosure 1
TO: CAU OPER
PLAN 1-50

SCHEDULE OF EVENTS

15 February 1950	Prepare course of instructions and write Manuals and Handbooks.
10 March 1950	Manual completed and ready for reproduction
25 March 1950	Student umpires arrive and are processed.
27 March - 4 April 1950	School for umpires.
5 - 8 April 1950	Umpires join units - field.
15 April 1950	Reconnaissance begins.
21 - 27 April 1950	Air units arrive at maneuver bases.
24 April 1950	Maneuvers begin.
8 May 1950	End of maneuver - prepare final reports.
15 May 1950	Submission of Air Umpire Final Report.

Inclosure 2
to CAU Oper
Plan 1-50

IR UMPIRE ORGANIZATION



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AIR UMPIRE SECTION (SWARMER)
Fort Bragg, North Carolina

Annex "A"
To Chief Air Umpire
Operations Plan
1-50

27 February 1950

RULES AND INSTRUCTIONS

ANNEX A

Purpose:

1. The purpose of this annex is to prescribe those rules and instructions necessary for Air Umpires to properly judge and observe the effectiveness of air operations in joint service operations; examine the validity of current techniques and procedures for joint umpire operations, and to accumulate knowledge and data concerning the principles governing a joint air support-airborne-troop carrier operation; evaluate capabilities of new items of equipment for their suitability in joint operations.

Coordination of Air and Ground Umpires:

2. In order that the Air Umpire Section proceeds on a coordinated basis the following outline will be utilized as a guide:

a. The Air Umpire Section will umpire the following:

(1) All air-to-air combat. Damage will be assessed in accordance with damage assessment tables, Section VII, this annex.

(2) All troop carrier responsibilities in the Airborne assault.

(3) Effectiveness of each air attack, both air-to-air and air-to-ground expressed in percentage. Effectiveness of attack will be determined in general by:

a. Tactics employed.

b. Types of formation flown.

c. Overall operation of the unit with regard to such matters as briefings, take off and join up, ability to operate in existing weather conditions, and whether or not the proper target was actually located and attacked.

(4) All aerial reconnaissance missions, both visual and photographic.

(5) Damage to airbases and aircraft on air bases by hostile attack.

(6) Damage inflicted on attacking aircraft by air base defense.

(7) Operation of Tactical Air Control Center and Subordinate Echelons with respect to overall effectiveness in controlling aircraft, passing on necessary information, detecting incoming hostile air attacks, and integration of communications with ground anti-aircraft defense in the assault area.

b. The Ground Umpire Section will umpire the following phases of air operations:

(1) The preparation for Emplaneing in aircraft, the actual "jump" and operations of the airborne unit thereafter.

(2) Damage to all ground targets by attacking aircraft.

(3) Damage to attacking aircraft by ground anti-aircraft defenses.

3. Coordination of Logistics Umpiring.

a. Planning Phase.

(1) All Air Umpires:

a. Judge the appropriateness of directives issued to bring required items for air supply to loading points.

b. Judge concurrently with the Ground Umpires, the preparation of loading plans of Air Force units with Airborne units. Also, observe the adequacy of aircraft provided and combat loading. Determine further if these plans support the tactical requirements for the units.

b. Preparation Phase.

(1) All Air Umpires:

Determine the completeness and adequacy of the Air Force units preparations for the maneuver and corrective action taken as a result of discrepancies discovered.

c. Assault Phase.

(1) All Air Umpires

Observe handling of air force materials to determine that appropriate procedures are followed in handling equipment or cargo by all air force organizations and that delivery schedules are met in order to meet tactical commitments.

d. During free phases, the Invasion and Defense Forces will operate under their respective plans to carry out their assigned missions. Both Invasion and Defense Forces will be umpired. In the event that opposing actions are such that no contacts will result, the Chief Umpire, with the concurrence of the Maneuver Commander, will take such action as he may deem desirable to keep contact between the opposing forces.

e. During controlled phases, the Defense Force will be employed in general conformance with FMs 30-101, 30-102, 30-103, 30-104 insofar as is necessary to insure adequate training of the Invasion Force. Basically, the Defense will be planned, organized and executed under the supervision of the Defense Commander. The Defense and Invasion Plans will be studied by the Chief Air Umpire and Control Plans prepared to insure inclusion of training. These control plans will control air missions and action by the Defense to insure meeting training objectives. Control plans will be consolidated by the Chief Umpire. After approval by the Maneuver Commander, control plans will be forwarded to the Defense Commander for execution. Local adjustments may be made to control plans during the execution phase by the Chief Air Umpire as may be required for successful execution of the exercise. The Chief Umpire will be kept informed of control plan changes. During controlled phases, the Invasion Force will be umpired, the Defense Force will be observed, and casualties assessed as appropriate.

f. The consolidated control plan will be distributed to the Maneuver Commander, Defense Commander and Umpire Group only, prior to completion of exercise.

4. Phases of Air Umpiring.

a. Each Umpire will judge certain phases of air operations for the purpose of this exercise. Where damage assessment is made by other than Air Umpires, the Air Umpire will make an evaluation of the attack and include it in the Air Umpire's final report to the Chief Umpire.

b. Ground and Air Umpires will judge their respective components throughout airborne planning and execution. Casualties to aircraft and crews will be assessed by Air Umpires, and casualties to airborne elements will be assessed by Ground Umpires, if appropriate. Any casualties to airborne elements will be restored prior to reaching of drop zone.

c. Coordination of prisoner exchange will be as prescribed by Chief Ground Umpire.

d. Coordination of "out of action" will be as prescribed by Chief Ground Umpire for Army equipment, and will be as prescribed by Chief Air Umpire for aircraft and related aviation equipment in Section VII.

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e. Each Umpire Group will judge and observe communications within its scope of umpiring. See Annex B .

5. Umpiring Air Operations.

a. All air-to-air operations will be judged by air umpires.

The following will be considered in evaluating air operations generally:

(1) Tactics employed.

(2) Types of formation flown.

(3) Gaining and maintaining air superiority.

(4) Escort and defense of troop carrier.

(5) Overall operation of the unit with regard to briefings, communications, takeoff and join up, and ability to operate in existing weather conditions.

(6) Operation as directed by the Tactical Air Controller.

(7) Relative performance, armament.

b. Interceptions.

Interceptions will be judged on the following:

(1) Element of surprise.

(2) Altitude Advantage.

(3) One pass only by attackers (There will be no melees or Dog Fights).

(4) Whether or not the proper target was actually located and attacked.

c. Escort Missions will be judged on the following:

(1) Joint planning.

(2) Rendezvous.

(3) Tactics employed.

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d. Combat Air Patrol will be judged on the following:

(1) Ability to follow directions from the Air Controller.

(2) Receipt of sufficient instructions from the Air Controller to make an interception.

(3) Tactics employed.

e. Air-to-surface operation will be judged by the following:

(1) Joint planning.

(2) Tactics employed.

(3) Types of formations flown.

(4) Overall operation of the unit with regard to briefings, critiques, takeoff and join up, ability to operate in existing weather conditions.

f. Deep and Close Air Support will be judged by the following:

(Damage assessment by ground umpires, except attacks on air installations).

(1) Operation as directed by the Tactical Air Controller.

(2) Element of surprise.

(3) Correct time over target.

(4) Whether or not the proper target was actually located and attacked.

(5) Type of attack and accuracy resulting.

(6) Proper armament.

g. Troop Carrier missions will be judged on the following:

(1) Joint planning as to selection and preparation of route to drop zone.

(2) Coordination with fighter escort.

(3) Joint training.

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(4) Aerial resupply and evacuation of wounded.

(5) Tactics employed.

(6) Types of formation flown.

(7) Overall operation of the unit with regard to briefings, take-off and join up and ability to operate in existing weather conditions.

(8) Whether or not the proper drop zone was reached and the jump properly performed.

(9) Return route and tactics employed.

h. Aerial reconnaissance missions will be judged on the following:

(1) Joint planning.

(2) Preparation.

(3) Results of visual reconnaissance.

(4) Results of day photographic reconnaissance.

(5) Results of night photographic reconnaissance.

(6) Dissemination of information gained on the mission.

(7) Whether or not the reconnaissance covered the objective or proper target.

i. All simulated operations will be within the limits as established by the Maneuver Commander and will be judged by Air Umpires in the same manner as an actual action:

(1) When aircraft are dispatched on a simulated mission, a like number of the same type will be grounded for the same period of times that it would take to complete the mission and return to home base and re-service.

(2) Damage will be assessed to both sides in accordance with the appropriate damage assessment tables.

(3) Aircraft grounded as a result of simulated operations may be utilized for flights which are not part of the maneuver.

(4) Aircraft are not subject to capture. They are only subject to simulated destruction.

6. Assumptions (To be announced by Maneuver Commander, at a later date.)

7. Decisions of Air Umpires:

a. Since the primary purpose of this exercise is to provide the maximum training for all personnel and units involved, the Air Umpires will be guided in rendering decisions on assessment of damage as outlined in section VII, Damage Assessment Tables.

b. It is desired that competition and decisions creating a sense of victory or defeat be avoided between the participating units in favor of promoting combined service training.

c. Air Umpires will make every effort to familiarize themselves with the training objectives of the other services.

d. The intent and spirit of unification of the services must be adhered to through close cooperation and understanding of mutual problems.

e. When existing umpire rules require amplification, the approved doctrines of the various services may be employed as guides. In the interest of using newly-developed umpire rules or methods based on recent exercises, modifications may be based upon reports and recommendations of these exercises where applicable.

f. Air Umpires will be assigned to units but are not required to be a part of the unit to which assigned. An officer designated to umpire his own unit will perform his duties impartially. His reports are not subject to review by any officer of the unit of force to which he is assigned.

g. All unit umpires will conform to umpire rules and procedures; however, units may call on umpires for decisions when needed, or for clarification of decisions already made.

8. <u>Air Base.</u>

a. The following Air Bases will utilized during the exercise as indicated:

	For the Defense	For the Invasion Forces
Pope AFB	X	X
Congaree AFB		X
Langley AFB	X	
Shaw AFB		X
MacKall AFB		X
Oceana NAS		X

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Campbell AFB

Laurinburg-Maxton AFB

9. Distinguishing markings of Aircraft.

To be announced by Maneuver Commander.

10. Security:

a. All classified material will be handled in accordance with the provisions of:

(1) JANAP 122

(2) Air Force Regulation 205-1

(3) Command Security Manuals and instructional documents of various crypto systems employed by using agencies.

b. If maneuver play dictates, orginators of correspondence, dispatches, and documents for use in Exercise SWARMER will designate two security classifications for materials prepared.

c. On correspondence and documents the maneuver classification will be shown below the actual classification. For Example:

RESTRICTED

SWARMER TOP SECRET SWARMER

d. In the texts of dispatches the words Swarmer SECRET (or other classification designated) will be included to show the maneuver classific tion. However, the actual classification will govern the necessary handling and servicing of dispatches and transmission of documents between headquarters.

e. Air Umpires will not divulge any Swarmer Umpire information to either the Invasion or Defense Forces.

11. Psychological Warfare:

a. Both the Invasion Force and Defense Force Commanders may use psychological warfare during the Swarmer exercise. Plans should include all measures that would be appropriate and practicable in actual war, but those measures not to be executed (simulated) should be stipulated as such.

b. Actual techniques employed will be confined to those of the Tactical Psychological Warfare; the normal civil life of the maneuver area must not be disturbed.

c. In order to avoid actual results that would be harmful to United States interest, the following policies are set forth to govern the execution of planned measures.

(1) No actual psychological warfare measures will be executed that will offend any group of United States citizens on account of race, religion, political or geographical background.

(2) No actual psychological warfare measures will be planned or executed that will intimate that opposing forces represent or resemble any nation other than the United States or "Aggressor".

(3) No actual psychological warfare measures will be executed that will tend to cause ill-feeling among branches of the U.S.Armed Forces.

(4) Psychological warfare themes aimed at the morals of opponents may be planned, but not included, in propaganda. Air Umpire these activities will be observed and commented in Air Umpire reports.

12. Intelligence

a. The Maneuver Commander will act as overall coordinating authority in matters pertaining to intelligence.

b. The Invasion and Defense Commanders will obtain intelligence through agencies normally available to themselves and their component commanders.

C. The Invasion and Defense Forces will consist mainly of actual Units assigned, but may include simulated units determined by the Maneuver Commander (after consultation with Invasion and Defense Commanders) to be necessary in order to insure meeting the training requirements set forth by the joint Chiefs of Staff.

13. Administrative, Logistical and Medical:

Air Umpires will observe and report on those logistical, fiscal, administration and medical aspects of the exercise that have a direct bearing on the effectiveness of the operational unit in combat in accordance with check-list provided by the Chief Air Umpire.

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Umpires of all echelons will enforce supply discipline to insure conservation, care, and preservation of supplies and equipment.

14. Uniforms, Air Umpires:

a. Air Umpire will wear the prescribed Air Force Uniforms.

b. Distinctive insignia is to be prescribed later.

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Appendix 1 to Annex A
Chief Air Umpire Operation Plan 1-50

1 March 1950

Responsibilities of Air Force Umpires

1. Invasion and Defense Force Umpires will be responsible for accomplishing the following:

a. Observe, evaluate and report on staff and command functions of the Force to which assigned. This will include planning, operations, intelligence, administration and logistics.

b. To receive, evaluate and consolidate reports from subordinate Umpires for preparation and forwarding to the Chief Air Umpire.

c. Organize, supervise and monitor umpires of the Force's subordinate elements to provide umpire coverage of all phases of the maneuver and to compile data concerning the performance of these units.

d. Perform other functions as directed by The Chief Air Umpire.

2. Airdrome Umpires will be responsible for accomplishing the following:

a. Organize, supervise and monitor the activities of the Wing, Group and Squadron Umpires.

b. Assimilate, consolidate and forward information and/or reports received from subordinate umpires to the Force Umpire.

c. Establish himself in an accessible location on the airdrome in order to facilitate the efficient functioning of the Umpires.

d. Assess damage inflicted to airdrome facilities and/or aircraft operations.

e. Prepare final umpire reports for submission to the Force Umpire with the assistance of subordinate umpires.

f. Perform other functions as directed by the Force Umpire.

3. Wing Umpire will be responsible for accomplishing the following:

a. Observe, evaluate and report on staff and command functions of the Wing to which assigned. This will include

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planning, operations, intelligence, administration and logistics.

b. To receive, evaluate and consolidate reports from subordinate Umpires for preparation and forwarding to the Airdrome Umpire.

c. Organize, supervise and monitor umpires of the subordinate element to provide umpire coverage of all phases of the Wing's part in the maneuver and to compile data concerning the performance of these units.

d. Assist Airdrome Umpire in preparation of final umpire report.

e. Perform other functions as directed by the Airdrome Umpire.

4. Group Umpires will be responsible for accomplishing the following:

a. Observe, evaluate and report on staff and command functions of the Group to which assigned. This will include planning, operations, intelligence, administration and logistics.

b. Direct, supervise and coordinate subordinate umpires in order to provide adequate coverage of all phases of the maneuver and to compile data concerning the performance of these units.

c. Assimilate information and reports from subordinates for submission to the Wing Umpire.

d. On Group missions, assess aircraft damage in accordance with damage assessment tables within his sphere of responsibility.

e. Perform other functions as directed by the Wing Umpire.

5. Squadron Umpire will be responsible for accomplishing the following:

a. Observe, evaluate and report on staff and command functions of the Squadron to which assigned. This will include planning, operations, intelligence, administration and logistics.

b. Appoint, instruct, direct, supervise and coordinate organic umpires in order to provide adequate coverage of all phases of the Squadron's part in the maneuver and to compile data concerning the performance of the unit.

c. Prepare reports for submission to the Group Umpire.

d. Accompany aircraft on Squadron missions within his reasonable capabilities. Requirements exceeding his capabilities will be met by the selection of organic air umpires.

e. Perform other functions as directed by the Group Umpire.

6. Tactical Air Control Center Umpire will observe, rate and report to the Force Umpire on the TACC and Tactical Air Control Group to which assigned on the following:

a. Ability of Unit to clearly present a continuous and timely representation of the air picture.

b. Ability of Unit to efficiently utilize organic communication facilities and equipment.

c. Ability of Unit to identify all friendly aircraft through knowledge of flight plans, radar, data, and other related information.

d. Ability of Unit to utilize information of air situation to effectively employ fighter aircraft and AAA.

e. Ability of Unit to safeguard equipment and personnel.

f. Ability of the Tactical Air Control Group to perform its primary mission. This mission is to observe, evaluate and report on staff and command functions of the TACG to which assigned. This will include planning, operations, administration and logistics.

7. Tactical Air Direction Center Umpire will observe and report to the Tactical Air Control Center Umpire on the following:

a. Ability of Unit to efficiently operate organic radar and IFF equipment, reporting data [illegible] with minimum time delay according to Standard Operating Procedure.

b. Ability of Unit to clearly present a continuous and timely presentation of the air picture.

c. Ability of Unit to utilize air information to control combat forces.

d. Ability of Unit to efficiently utilize organic communication equipment.

e. Ability of Unit to safeguard equipment and personnel.

8. Air Liaison Officers: There will be provided two Air Liaison Officers (U.S. Forces, Aggressor Force) who will be responsible to the Chief Air Umpire. They will perform the following duties:

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a. U.S. Force Liaison Officer will maitain liaison with Army Ground Forces and Aggressor Liaison Officer, and advise him of location, disposition and plans of the United States Forces.

b. Aggressor Force Liaison Officer will maintain liaison with United States Force Liaison Officer and advise him of location, disposition and plans of the Aggressor Force. This information will not be divulged to the U. S. Forces Commander unless specifically directed by the Chief Air Umpire.

c. The Aggressor Force Liaison Officer will maintain liaison with the Aggressor Force Commander and keep him informed of the U. S. Forces dispositions and plans.

d. Force Liaison Officers will maintain contact with the Chief Air Umpire at all times and will keep him informed of Air Force and Army dispositions.

e. Force Liaison Officers will perform such other duties as may be directed by the Chief Air Umpire from time to time.

9. Radar Umpire Officers will be responsible for accomplishing the following:

a. Observe, rate and report on the functions of the radar site to which assigned. This will include interceptions, plotting, siting, condition of equipment and capabilities of operating personnel. The latter will particularly include the recognition and action taken against electronic counter-measures.

b. Prepare reports for submission to the TACC Umpire.

c. Perform other functions as directed by the TACC Umpire.

10. Joint Operation Center Umpires will observe, rate and report to the Chief Air Umpire on the JOC to which assigned on the following:

a. Ability to coordinate staff and command functions, to include planning within the JOC.

b. Perform other functions as directed by the Chief Air Umpire.

11. Signal Battalion Umpire will observe, rate and report to the Force Umpire to include the following:

a. Ability to perform staff, command and operational functions. This will include planning, administration and logistics.

b. To review and evaluate the adequacy, and ability to perform the communication plan published by higher headquarters as regards the necessary provisions to accomplish the mission of the Signal Battalion.

c. Ability of Unit to efficiently operate organic communication equipment.

d. Ability of Unit to safeguard equipment and personnel.

12. Air Umpires at all echelons will be responsible for determining the degree to which participating organizations employ security practices in the preparation, transmission, reception, storage, recording and destruction of classified materials. Umpires will be guided by the provisions of Air Force Regulation 205-1 and JANAP 122.

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Appendix 2 to Annex "A"
CAU Operation Plan 1-50

27 February 1950

AIR AGGRESSOR CONTROL PLAN

1. Definition:

a. The Control Plan controls specific air action by the Aggressor Air Force in order to achieve training objectives.

2. Purpose:

a. The purpose of Control Plan is to substitute wartime unknown factors similar to those encountered in actual combat for known factors which are usual in peace-time maneuvers.

3. Concept:

a. The initiation of Air Operations rests with the Aggressor Air Forces and the least possible interference in planned missions is anticipated.

b. The responsibility of controlling such missions rests with the Chief Air Umpire in order to avoid violations of certain air concepts established by doctrine.

c. The primary purpose of this maneuver is to provide training for all participants, and the Control Plan will contribute in accomplishing this purpose. Furthermore it is highly desirable that maximum utilization be made of all aircraft in the maneuver without violating accepted concepts.

d. The Aggressor Control Plan will go in effect on the day the Invasion Forces achieve Air Superiority. The Chief Air Umpire will determine the date when Air Superiority has been achieved.

4. Operations:

a. After Air Superiority has been achieved, Aggressor Air Force will forward all contemplated missions to the Chief Air Umpire for approval and control as to their feasibility in the light of existing situations.

b. Defensive missions requiring spontaneous decisions will depend on Aggressor's capabilities and action of the opposition.

c. Offensive missions must be submitted six (6) hours in advance of execution.

d. In addition to Air Aggressor planned missions, the Chief Air Umpire may order specific missions. This may be done to exploit the flexibility of opposing Air Forces and provide the desired training for participants. All such strikes will be ordered as much in advance as practicable.

e. Planned air strikes may be changed by the Chief Air Umpire as the situation dictates, in order to achieve successful execution of the exercise.

f. The Chief Air Umpire will be kept informed of implementation of Control Plan.

g. Attached is numbered list of type strikes which may be ordered by the Chief Air Umpire when appropriate.

TYPES OF AIR STRIKES WHICH MAY BE ORDERED BY
CHIEF AIR UMPIRE DURING CONTROLLED PHASE

1	Fighter attack (s) on Troop Carrier Serial (s).
2	Fighter bombing, rocket, and strafing attack on U. S. Air Forces Bases.
3.	Fighter mission (s) in close support of Aggressor Ground Forces.

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Appendix 3 to Annex "A"
CAU Operation Plan 1-50

Air Umpire Visual Signals.

1. It is desired to develop the use of visual signals for Air Umpiring in order to reduce communications traffic.

2. Flying Air Umpires should encourage the use of Visual Signals in transmitting the percentage of effectiveness of an air strike to the flight leader. The Air Umpire will include such percentages in his report to the next higher Air Umpire echelon.

3. Flying Air Umpires are responsible for briefing flight leaders in the employment of visual signals.

4. Visual signals for indicating the percentage of effectiveness of an air strike will be transmitted by the Air Umpire if practicable. This may be accomplished by flying parallel to the flight leader and executing the applicable signal. A list of sample signals follow:

a. Mission complete failure - Dive the aircraft.

b. Mission 25% effective - Rock wings.

c. Mission 50% effective - Porpoise aircraft.

d. Mission 75% effective - Fishtail aircraft.

e. Mission 100% effective - Pull up into a steep climb.

(These signals may be revised if necessary)

5. At the completion of the exercise Air Umpires will submit the list of signals used and make recommendations as to their practicability for future exercises.

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Air Safety

1. Air Umpires will be completely familiar with USAF and Naval fl- flying safety regulations. Reports of Violations will be made in Air Umpire Reports.

2. In addition the following safety rules will be observed, and any violations will be reported by Air Umpires:

a. Jet aircraft will not attack other aircraft closer than one thousand (1,000) feet. Propeller - driven aircraft will not attack other aircraft closer than five hundred (500) feet.

b. Individual dog-fighting between aircraft is prohibited.

c. Only one pass will be allowed in any one engagement.

d. Transport type aircraft will not be attacked. Intent to attack may be signified by a parallel pass with a minimum of one thousand (1,000) feet clearance.

e. Unnecessary low or "hot shot" flying.

3. Air Umpires will insure that they are completely familiar with the established Search and Rescue procedures.

4. Airdrome Umpires will check the following:

a. Adequacy of crash fire-fighting equipment.

b. Smoking near parked aircraft.

c. Fire guards when aircraft is started.

d. Fast and/or careless taxiing.

e. Check for control of takeoff, landing and parking of aircraft.

f. Protection of troops from propellers.

g. Any laxity - protection of personnel and equipment.

h. Provisions for care of actual and simulated casualties.

5. Flying Umpires where applicable will check:

a. If troops and passengers are instructed in wearing of parachute and wearing of safety belts.

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b. If smoking regulations are enforced in aircraft.

c. On any violations of safety regulations or dictates of common sense affecting safety.

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Appendix 5 to Annex "A"
CAU Operation Plan 1-50

Damage Assessment

1. Damage assessment will be in accordance with tables contained in this Handbook:

a. Air to air:

(1) Joint planning/training.

(2) Overall tactics including formation(s), axis of of attacks(s), element of surprise, altitude advantage, air superiority measures, relative aircraft performance, etc.

(3) Unit operational readiness/effectiveness including briefing(s), communications, takeoff/join-up, existing weather capabilities, mission results, critique(s), etc.

(4) Compliance with Tactical Air Controller instructions and sufficiency of such directions. (Proper target actually located and attacked at time specified, with armament required).

(5) One pass only by attacker(s) (No melees or dog fights).

b. Air to Surface:

See a (1), (2), (3), and (5) above.

c. Escort:

(1) See a (1), (2), (3), and (5) above.

(2) Rendezvous.

(3) Troop Carrier Serial(s) defense.

d. Combat Air Patrol (CAP):

See a (2), (3), (4), and (5) above.

e. Interception:

See a (2), (4), and (5) above.

f. Night/All Weather Interceptions:

See a (2), (3), (4), and (5) above.

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(Damage assessment made by control center umpire(s).

g. Deep/Close Air Support:

See a (1), (2), (3), and (4) above.

(Damage assessment made by Army Umpires except upon air installations).

h. Troop Carrier:

(1) See a (1) above.

(2) Selection and preparation of route(s) to objective(s).

(3) Air movement of airborne troops.

(4) Fighter escort coordination.

(5) Air supply and evacuation.

(6) See a (2) and (3) above.

i. Air Reconnaissance:

(1) See a (1), (2), and (3) above.

(2) Information dissemination procedures.

(3) Whether pilots adjudged casualties and furnished mission report(s)/photograph(s) to unit(s).

j. Simulated Operations:

(Will be within limits established by Maneuver).

Commanded and umpired in same manner as actual action(s).

2. Aircraft Ruled Out of Action:

a. Aircraft that are part of a formation, ruled out of action by Air Umpires, will continue on with the remainder of the formation, but will not be counted as attacking the target for damage assessment purposes.

b. Single aircraft (including liaison type and night intruders) ruled out of action by appropriate umpires will return to base immediately when so instructed by the umpire.

c. Aircraft ruled out of action will be available as replacements upon return to home base only after having beem completely serviced.

d. Aircraft on the surface, ruled out of action due to bombing attacks on the airdrome, will be considered out of action for the same period of time that the airdrome is closed and/or ruled out of action in accordance with damage assessment tables X and XI.

e. Aircraft on the surface, ruled out of action due to strafing attacks, will be available as replacements in thirty (30) minutes elapsed time after termination of attack.

(See Damage Assessment Tables VII and VIII).

f. Aircraft on the surface, not damaged by strafing attacks, (Damage assessment Tables VII and VIII), will be grounded only for the time interval that airdrome is closed in accordance with Damage Assessment Table IX.

g. Crews of out-of-action aircraft will not divulge any information concerning flight upon return to base, and will maintain radio silence for the out-of-action period except in case of emergency.

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Inclosure 1
to Appendix 5
Annex "A"
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1. Damage assessment tables for use by flying Air Umpires are as follows:

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Inclosure 2
to Appendix 5
Annex "A"
CAU Oper
Plan 1-50

27 February 1950

DAMAGE ASSESSMENT

ANTI-AIRCRAFT VS AIRCRAFT

1. a. GENERAL: Aircraft lost as a result of anti-aircraft fire will be calculated by selecting the proper loss, (that is, the loss shown for the number of aircraft and number of batteries effective), in the basic loss tables as shown in Table 1 and by correcting this figure as shown in subsequent tables.

b. Effectiveness of Guns:

The table of basic aircraft loss (Table 1) to heavy anti-aircraft artillery is calculated on the assumption that all guns of all batteries are fully effective. If the effectiveness of four batteries has been determined by the AAA Umpire to be .25, .80, 1.00 and .50, add these figures. The answer (2.55) gives the number of batteries to consider for a collected basic loss number. When anti-aircraft artillery is not physically present, the penalties on batteries should be disregarded, and the basic loss facters in Tables 1 and 7 will be used.

TABLE 1 - BASIC AIRCRAFT LOSS TO GUNS ("X" VALUE)

Number of Aircraft	Number of 90mm Batteries Effective					
	1	2	3	4	5	6
	Aircraft Losses					
1	0.30	0.67	1.00	1.00	1.00	1.00
2	.30	..67	1.00	1.33	1.50	2.00
3	.30	.75	1.00	1.50	1.87	2.25
4	.40	.80	1.00	1.50	2.00	2.40
6	.42	.90	1.20	1.50	2.00	2.40
8	.48	..96	1.20	1.60	2.40	2.80
9	.56	1.00	1.35	1.80	2.70	3.15
12	.60	1.20	1.80	2.40	3.00	3.60
16	.80	1.60	1.92	2.72	3.20	4.00
24	.96	1.68	2.40	3.12	4.08	4.80

NOTES:

If only a fraction of a battery is effective, interpolate between batteries. Example: 3.5 batteries effective against 12 attacking aircraft result in the loss of 2.10 aircraft $\frac{(1.80 + 2.40)}{2} = 2.10$.

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c. Altitude ("A" Factor)

Calculation of rounds fired and accuracy of rounds result in the following corrections (Table 2)

TABLE 2 - ALTITUDE ("A" FACTOR)

Altitude	"A" Factor
3,000	0.70
6,000	.78
9,000	1.00
12,000	.74
18,000	.17
20,000	.018

d. Speed of Aircraft (S" Factor)

The corrections to be applied to the losses due to speed of aircraft is shown in Table 3.

TABLE 3 - SPEED ("S" FACTOR)

Speed of Aircraft	"S" Factor
180	1.33
200	1.20
220	1.09
240	1.00
260	.92
280	.86
300	.80
320	.70
400	.50
500	.30

e. Evasive Action ("V" Factor)

The table of basic loss (Table 1) assumes that no evasive action is taken. For loss reduction due to evasive action, factors listed in Table 4 will be employed.

TABLE 4 - EVASIVE ACTION ("V" FACTOR)

Evasive Action	"V" Factor
Evasive Action	0.30
No Evasive Action Employed	1.00

NOTE:

Evasive action is credited if the attacking aircraft is climbing, diving or turning, to avoid anti-aircraft fire.

f. Formation ("F" Factor)

The table of basic loss assumes a tight formation. For loss reduction due to formation, correction factor "F" (Table 5) will be employed.

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TABLE 5 - FORMATION ("F" FACTOR)

FORMATION	"F" FACTOR
Tight	1.00
Loose	.85
Very Loose	.70

NOTES:

(1) Tight Formation: The interval between aircraft does not exceed a lateral distance of one wing span or a longitudinal distance of one aircraft length.

(2) Loose Formation: The interval between aircraft varies from two to four wing spans and aircraft lengths.

(3) Very Loose: The interval between aircraft exceeds four wing spans and aircraft lengths.

g. Subsequent Runs ("R" Factor)

Table of Basic Loss assumes a single run through the zone of fire. Additional runs will be assessed by applying the factor "R" (Table 6) to losses determined for the first run.

TABLE 6 - SUBSEQUENT RUNS ("R" FACTOR)

Run	"R" Factor
First Run (No Warning)	0.50
First Run (Prior Warning)	1.00
Second Run	1.50
Third Run	2.00

(1) If the formation attacks in waves, which are so widely separated that each wave may be engaged by the entire anti-aircraft artillery defense, the formation will be considered as making two or more runs, and the losses increased on the subsequent runs.

(2) When anti-aircraft artillery units are actively participating in a maneuver, it will be considered that prior warning has been received if the target is engaged before it reached the perimeter of the anti-aircraft artillery defense.

h. Application of Basic Loss Table and Corrections

(1) Losses for a particular attack may be determined by the following formula:

Loss = ASVFRxX

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Example: 12 aircraft flying at 6000 feet and 220 MPH in loose formation, employing evasive action, attack on Airdrome where there are five (5) batteries of 90mm guns of which only 4½ batteries are effective. Prior warning has been received.

X =	2.7	(From Table 1)
A =	.78	(From Table 2)
S =	1.09	(From Table 3)
V =	.60	(From Table 4)
F =	.85	(From Table 5)
R =	1.00	(From Table 6)

Loss = .78X 1.09 X .60 X .85 X 1.00 X 2.7 = 1.17 Aircraft. The loss of one aircraft will be assessed.

(2) Value of "X" in basic loss table may **EXCEED** 100 percent of actual aircraft. If final answer exceeds 100 percent of aircraft, 100 percent loss will be assessed.

(3) If the entire formation makes a second run over the target, the number of aircraft against which losses will be assessed will be the net number of remaining after the first run.

2. Losses Due to Automatic Weapons:

The table of basic loss (Table 7) due to automatic weapons has been compiled with certain characteristics of aircraft, automatic weapons, guns/battery, etc; (FM 105-5) being assumed. A 40mm gun is considered equivalent in firepower to a quadruple mount cal. .50 machine gun. Losses will be calculated from the basic loss tables and corrections made in the same manner as for the 90mm anti-aircraft guns, using the formula: Loss = ASVFRxX. Losses of aircraft to Automatic Weapons will not be assessed unless such aircraft are at an altitude of 6000 feet (above terrain or below.

a. Effectiveness of Automatic Weapons:

When the number of batteries which are effective against a flight of aircraft has been determined by a Ground Umpire, aircraft losses may be calculated by means of loss tables.

b. Basic Loss Table for Automatic Weapons:

Table 7 indicates the basic loss of aircraft ("X" Value) to automatic weapons.

TABLE 7 - BASIC LOSS TO AUTOMATIC WEAPONS ("X" VALUE)

Number of Aircraft	Number of Batteries Effective					
	1	2	3	4	5	6
	Aircraft Losses					
1	1.0	1.0	1.0	1.0	1.0	1.0
2	1.50	2.0	2.0	2.0	2.0	2.0
3	2.5	3.0	3.0	3.0	3.0	3.0
4	3.0	4.0	4.0	4.0	4.0	4.0
6	3.2	5.0	6.0	6.0	6.0	6.0
8	3.5	6.0	8.0	8.0	8.0	8.0
9	3.5	6.0	8.0	9.0	9.0	9.0
12	3.5	6.0	8.0	9.5	11.0	12.0
16	3.5	6.5	8.5	10.0	11.5	14.5
24	4.0	7.0	9.0	10.0	12.0	15.0

c. Altitude Correction ("A" Factor)

Calculation of r-unds fired and average ranges result in the foll wing corrections for altituc : ("A") (Table 8) to be made, due to altitude of the attack:

TABLE 8 ALTITUDE ("A" FACTOR)

Altitude (FT)	"A" Factor
200	0.25
500	.33
1,000	.61
1,500	.67
2,000	1.00
2,500	.88
3,000	.58
3,500	.48
4,000	.29
4,500	.24
5,000	.13
5,500	.10
6,00	.07

d. Speed Correction ("S" Factor)

The correcti ns f und in Table 9 will be made to basic loss table for the speed of the attacking aircraft.

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TABLE 9 - SPEED ("S" FACTOR)

Speed of Aircraft (M P H)	"S" Factor
180	1.40
200	1.25
220	1.12
240	1.00
260	.90
280	.83
300	.78
320	.70
400	.40
500	.15

e. Evasive Action ("V" Factor):

When it is discernible that the attacking aircraft are maneuvering to avoid anti-aircraft fire, evasive action will be credited.

Corrections found in Table 10 will be made to Basic Loss Table for evasive action taken:

TABLE 10 - EVASIVE ACTION ("V" FACTOR)

Evasive Action	"V" Factor
Evasive Action	0.80
No Evasive Action Taken	1.00

f. Formation:

Corrections found in Table 11 will be made to Basic Loss Table to account for formation of attacking aircraft.

TABLE 11 - FORMATION ("F")

Formation	"F" Factor
Tight	1.00
Loose	.85
Very Loose	.70

NOTE:

For definitions of formations, see note 1, 2, and 3 under Table 5).

g. Subsequent Runs ("R" Factor)

The Basic Loss Table is computed for the first run over the zone of fire after prior warning has been received. The correction is made in accordance with Table 12.

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TABLE 12 - SUBSEQUENT RUNS ("R" FACTOR)

Run	"R" Factor
First Run (No Warning)	0.00
First Run (Prior Warning)	1.00
Second Run	2.00
Third Run	3.00

h. Combined Losses:

Losses to flights which are engaged by both guns and automatic weapons (Alt. between 3000 and 6000 ft.) will be the sum of the losses incurred from each type of anti-aircraft fire.

i. Umpires will assume that all airdromes will be defended by one Battalion of anti-aircraft automatic weapons and by one Battalion of 90 MM Guns, except where the number is determined by the development of the tactical situation. In this case the Umpire will be given prior notification.

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TABLE 13 - Jet Fighter Vs Jet Fighter - Surprise Attack

Aircraft Attacked	Losses of Aircraft Attacked												Losses of Aircraft Attacking											
	Attacking -												Attacking -											
	1	2	3	4	6	8	10	12	14	16	18	20	1	2	3	4	6	8	10	12	14	16	18	20
1.....	1	1	1	1	..	..	..	..	..	..	..	..	0	0	0	0	..	..	..	..	..	..	..	..
2.....	..	1	2	2	2	..	..	..	..	..	..	..	0	0	0	0	0	..	..	..	..	..	..	..
3.....	..	1	2	2	[illegible]	..	..	..	..	..	..	..	..	0	0	0	0	..	..	..	..	..	..	..
4.....	..	0	2	2	3	4	..	..	..	..	..	..	..	2	1	0	0	0	..	..	..	..	..	..
6.....	..	..	0	2	3	4	4	6	..	..	..	..	..	..	2	1	0	0	0	0	..	..	..	..
8.....	..	..	..	0	3	4	4	5	6	8	..	..	..	..	..	3	1	0	0	0	0	0	..	..
10....	..	..	..	..	2	3	5	6	7	8	9	10	..	..	..	..	1	1	0	0	0	0	0	0
12....	..	..	..	..	0	2	[illegible]	[illegible]	7	8	9	10	.	..	..	..	2	1	2	0	0	0	0	0
14....	..	..	..	..	..	0	[illegible]	4	7	[illegible]	8	9	..	..	..	..	..	1	2	2	0	0	0	0
16....	..	..	..	..	..	0	2	4	5	8	9	9	..	..	..	..	..	2	2	1	1	0	0	0
18....	..	..	..	..	..	..	[illegible]	1	4	5	8	9	..	..	..	..	..	..	3	3	2	2	0	0
20....	..	..	..	..	..	..	0	1	3	5	7	10	..	..	..	..	..	..	4	3	3	2	1	0

NOTE: When Jet aircraft attacked by conventional fighters - Multiply losses of aircraft attacked by a factor of 0.50.

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TABLE 14 - Jet Fighter vs Jet Fighter - with Prior Warning

Aircraft Attacked	Losses of Aircraft Attacked												Losses of Aircraft Attacking											
	Attacked by												Attacking											
	1	2	3	4	6	8	10	12	14	16	18	20	1	2	3	4	6	8	10	12	14	16	18	20
1.....	0	1	1	1	.	.	..	..	..	..	..	..	0	0	0	0	.	.	..	..	..	..	..	..
2.....	1	1	1	1	2	.	..	..	..	..	..	..	1	1	1	1	1	.	..	..	..	..	..	..
3.....	.	1	1	1	2	2	3	..	..	..	..	..	.	1	1	1	1	1	2	..	..	..	..	..
4.....	.	1	1	1	2	2	3	4	..	..	..	..	.	1	1	1	2	2	2	..	..	..	..	..
6.....	.	.	1	1	2	2	3	4	4	5	6	..	.	.	2	2	2	2	3	3	3	3	3	..
8.....	.	.	.	1	2	3	3	4	4	5	5	6	.	.	.	2	2	3	3	3	3	4	4	4
10....	.	.	.	.	2	2	3	4	4	5	7	8	.	.	.	.	3	3	3	3	3	4	4	5
12....	.	.	.	.	1	2	3	4	4	5	6	7	.	.	.	.	4	3	3	4	4	4	4	5
14....	.	.	.	.	.	2	3	4	4	5	6	7	.	.	.	.	.	4	4	4	4	5	3	5
16....	.	.	.	.	.	2	3	4	5	6	7	7	.	.	.	.	.	4	4	5	5	6	6	6
18....	.	.	.	.	.	.	3	4	6	7	8	8	.	.	.	.	.	.	5	5	5	6	8	8
20....	.	.	.	.	.	.	4	5	6	7	8	8	.	.	.	.	.	.	6	6	7	8	8	8

NOTE: When Jet Aircraft attacked by conventional fighters - Multiply losses of aircraft attacking by a factor DA

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TABLE 15 - Bombardment vs Fighter Aircraft

Number of Bombers	Bomber Losses – Fighters Attacking								Fighter Losses – Fighters Attacking							
	2	4	6	8	10	12	14	16	2	4	6	8	10	12	14	16
1.....	1	1	1	.	..	..	..	..	1	1	0	.	..	..	..	..
2.....	0	1	2	2	..	..	..	..	1	1	0	0	..	..	..	..
3.....	.	.	1	1	2	2	..	..	.	.	1	1	1	2	..	..
4.....	.	.	.	1	1	2	3	4	.	.	.	2	2	2	2	2
6.....	.	.	.	0	0	1	2	3	.	.	.	2	3	3	3	3
9.....	.	.	.	1	2	2	3	4	.	.	.	2	2	3	3	3
12....	.	.	.	2	2	3	3	4	.	.	.	2	3	3	3	4
15....	.	.	.	.	2	3	3	4	.	.	.	.	2	3	3	3
18....	.	.	.	.	.	2	3	4	.	.	.	.	.	3	3	3

NOTE: 'hen Jet Bomber attacked by conventional fighters - Multiply Bomber losses by a factor 0.50

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TABLE 16

Fighter vs Troop Carrier Aircraft
(without Escort)

Aircraft Attacked	Losses of Aircraft Attacked Attacked By-											
	1	2	3	4	6	8	10	12	14	16	18	20
1.......	1	1	1	1	•	•	••	••	••	••	••	••
2.......	2	2	2	2	2	•	••	••	••	••	••	••
3.......	2	3	3	3	3	•	••	••	••	••	••	••
4.......	2	3	4	4	4	4	••	••	••	••	••	••
6.......	2	4	6	6	6	6	6	6	••	••	••	••
8.......	2	4	6	8	8	8	8	8	8	8	••	••
10.....	2	4	6	8	10	10	10	10	10	10	10	10
12.....	2	4	6	8	12	12	12	12	12	12	12	12
14.....	2	4	6	8	12	14	14	14	14	14	14	14
16.....	2	4	6	8	12	16	16	16	16	16	16	16
18.....	2	4	6	8	12	16	18	18	18	18	18	18
20.....	2	4	6	8	12	16	20	20	20	20	20	20

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TABLE 17

Fighter vs Troop Carrier and/or Bomber
Aircraft (with Escort)

1. Losses to Troop Carrier and/or Bomber Aircraft with escort will be assessed after fighter losses are determined by use of Tables 13 and 14.

2. If the attacking fighters have gained air superiority through the use of the tables, the remaining attacking fighters will be credited with troop carrier and/or bomber aircraft destroyed in accordance with Tables 15 and 16.

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TABLE 18

Fighter vs Reconnaissance

If attack is pressed home by fighters against reconnaissance aircraft the loss will be one reconnaissance aircraft destroyed for one fighter attacking or one for one.

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TABLE 19

Losses of Aircraft on Ground as a Result of Strafing Attack (Aircraft not Dispersed)

NUMBER OF AIRCRAFT ON GROUND	NUMBER OF AIRCRAFT ATTACKING							
	1	2	4	6	8	12	16	24
	LOSSES							
3..............	1	1	1	2	2	2	3	3
6..............	1	2	2	3	4	4	5	6
9..............	2	2	3	4	5	6	6	7
12..............	2	3	4	5	6	7	9	10
16..............	2	3	4	6	8	9	11	13
20..............	2	4	5	7	10	12	15	16
2[illegible]..............	3	4	5	8	12	15	18	20
30..............	3	5	6	10	15	18	20	24
36..............	3	5	6	12	18	20	24	28
50..............	4	6	8	16	20	24	30	35
60..............	4	6	10	18	22	30	40	45
75..............	5	8	12	20	24	35	45	55

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TABLE 20

Losses of Aircraft on Ground as a Result of Strafing Attack (Aircraft Dispersed)

NUMBER OF AIRCRAFT ON GROUND	1	2	4	6	8	12	16	24
3..............	0	0	1	1	[illegible]	2	3	3
6..............	0	1	1	1	[illegible]	2	3	4
9..............	1	1	2	2	3	3	4	6
12..............	1	1	2	3	3	5	6	6
16..............	1	2	3	3	4	5	7	8
20..............	1	2	3	4	[illegible]	5	7	9
24..............	1	2	3	[illegible]	5	7	8	12
30..............	1	3	3	[illegible]	[illegible]	7	9	13
36..............	2	3	4	[illegible]	[illegible]	8	10	14
50..............	2	3	4	[illegible]	[illegible]	9	12	16
60..............	2	3	4	[illegible]	7	10	12	18
75..............	2	3	4	[illegible]	7	10	14	20

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TABLE 21

Fighter Attack on Airdromes

NUMBER OF FIGHTERS ATTACKING	[illegible] T[illegible]S FIELD CLOSED
2	0
4	10
6	15
[illegible]	20
10	2[illegible]
12	30
1[illegible]	35
2[illegible]	[illegible]5

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TABLE 22

Fighter Bomber Attack on Airdrome

NUMBER OF FIGHTER BOMBERS ATTACKING	MINUTES FIELD CLOSED
2........................	5
4........................	15
6........................	20
8........................	30
10........................	35
12........................	40
16........................	45

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TABLE 23

Bombardment Attack on Airdromes

NUMBER OF BOMBERS ATTACHING	MINUTES FIELD CLOSED
2.........................	15
4.........................	20
6.........................	30
8.........................	35
10........................	40
12........................	45
16........................	60

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TABLE 24

Losses of Aircraft Attacked by Night
or All-Weather Fighters.

1. Damage assessment of aircraft attacked by night or all-weather fighters will be made by the Umpire at the direction center which controls the intercepting aircraft. The aircraft will be judged destroyed when the radar screen at the control center shows a separation range of 1,000 feet or less.

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Appendix 6
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REPORTING PROCEDURE

1. Air Umpire reports will be limited to essential facts pertaining to the mission and operations of the organization umpired.

2. Classification : All operations reports will be classified "Swarmer Secret".

a. Weekly Report: A weekly report will be submitted by the Chief Air Umpire to the Chief Umpire summarizing air umpiring activities. The initial report will be submitted on Friday following the initiation of reconnanissance operations on or about 15 April 1950. Subsequent reports will be submitted by the Chief Air Umpire on Friday of each week until 8 May 1950.

3. Air Umpire Summaries:

a. All Air Umpires will maintain a Chronological Summary of alll air activities pertaining to Operation Swarmer of the units they are umpiring,-ie, Force, Airdrome, TACC,-(and TADC when reportin direct to the Force, Air Umpire). Air umpires will include in their chronological summary a resume of all air activities observed by air umpires within their sphere of operation. This summary will be maintained for future reference in compiling the final report for the Chief Umpire. Summaries from lower echelons will be submitted to Airdrome Umpires at the Airdrome Umpier's direction.

4. Air Umpire Reports:

a. Strike Report: A strike report will be submitted by Airdrome Umpires to the Chief Air Umpire, with information copies to the Chief Umpire and the respective Force Air Umpire, immediately upon completion of each strike. See inclosure 1 (Completed Strike Mission Dispatch Report) and inclosure 2 (Hostile Strike Dispatch Report) for form of report.

b. Daily Operational Summary Report: A daily operational summary report will be submitted by each TACC (and TADC when reporting direct to the Force Air Umpire) Air Umpire to the Chief Air Umpire with information copies to the respective Force Air Umpire and the Chief Umpire as of 2400 EST daily, covering the past twenty-four hours. This report must reach the Chief Air Umpire by 1200 hours the following day. Reports are to begin 17 April 1950 and continue to the end of the exercise. Report will be consolidated from locally observed sources and the TADCs under the control of the TACC and/or the TADC. For form of report see (inclosure 3) TACC and/or TADC Operational Summary Report.

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5. Voice Radio Report:

a. Flying Umpire: In order to give the appropriate umpires as much information as possible it is necessary for the flying umpires to make certain reports over the Air Umpire Broadcast Net during each flight. Each airdrome of the Invasion and Defense Forces has been assigned a code letter and all strikes from each base will be numbered serially. Required reports are as follows:

(1) Within five (5) minutes after becoming airborne, the Flying Umpire will broadcast over the Air Umpire Broadcast Net, the base code letter and strike number, point and time of departure, number and type of aircraft, armament, and mission and/or specific targets, if known. This transmission need not be receipted for, and should not be repeated more than once even though no acknowledgement is received. Message form and sample message as follows:

(a) Code name or letter of objective, if known; if code name or letter of objective is unknown, use code letter "X-RAY".

(b) Flight Code letter and number.

(c) Number and type of remaining aircraft.

(d) Mission and/or specific target, if known (coordinates, if land target).

(f) Bearing and distance from target and altitude.

(g) Sample report: GEORGE BASE THIS IS FLIGHT ABLE FIVE ONE ZERO X EIGHT [illegible] X THREE ANGLES X FULL LOAD AMMO AND EIGHT ROCKETS PER AIRCRAFT X [illegible] ABLE ABLE POSITION AT FIVE FOUR ZERO SEVEN [illegible] X BEARING ZERO MILES X ANGLES FIVE X.

(2) In the event of an air attack in support of friendly ground troops, the report outlined in 5. a. (1) should be directed to the Umpire of the unit requesting the air strike, See example 5. a (1).

(3) Immediately after an attack, the Flying Umpire will call over the Air Umpire Broadcast Net and notify the surface or ground umpire whether or not a successful attack was made. Message form and Sample message as follows:

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(a) Call letter of unit attacked, if known: if unknown use code letter "X-RAY".

(b) Flight code letter and number.

(c) Attack completed.

(d) Effectiveness of attack.

(f) Sample report: CAPTAIN THIS IS FLIGHT BAKER FIVE ONE X ATTACK COMPLETED X SEVENTY FIVE PERCENT X.

6. Transmission of Reports: Unit, Squadron, Group and Wing Umpires will transmit strike reports and any daily operational summary reports required by the Airdrome, TACC and/or TADC Umpire to the next senior umpire in the umpire chain of control by personal contact, telephone or other available means. Airdrome, TACC (and TADC when reporting direct to the Force Air Umpire) Air Umpires will submit the daily operational summaries to Air Umpire Communication Center on that station for transmission to the Chief Air Umpire. (See Communications Annex for further clarification and methods of transmission of information)

7. Final Reports:

a. Airdrome Umpires will submit reports in the following form to their respective Force Air Umpires for consolidation, indorsement and submission to the Chief Air Umpire. Through the employment of a forwarding letter in which the assigned mission of the unit is outlined the Air Umpires above will submit information regarding the following:

Part I - Planning Phase

Part II - Training Phase

Part III- Operation Phase

Part IV - Redeployment Phase (this part to cover redeployment of Umpire elements only).

b. The completed report from each force umpire will be submitted to the Chief Air Umpire by 10 May 1950

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COMPLETED STRIKE MISSION DISPATCH REPORT

1. The completed Strike (Mission) Dispatch Report (Message Form WD AGO Form 11-160) will be completed by answering the questions A thru J below and filling in the blanks opposite the same letter on the Message Form with these answers:

a. Complete identification of organization completing the attack including home base code, strike number and designation.

b. Armament used by attacking unit.

c. Complete identification of the target attacked to include the coordinates.

d. Time of the attack (actual strike time).

e. Percent effectiveness.

f. Numbers (by type) of own A/C participating in the attack.

g. Numbers (by type) and identification of hostile A/C engaged.

h. Losses of own A/C including type and number.

i. Damage of own A/C including type and number.

j. Estimated damage to hostile A/C.

Incl #1

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MESSAGEFORM	Msg Center No	Transmitting Means	Cryptograph or Clear Text	
Calls	Sta Ser NR	Precedence	Transmission Instructions Orignator	Date-Time Group
Action	Information	Exempt	Operating Signals	Group Count GR

From: (Originator)

SECURITY CLASSIFICATION
SWARMER SECRET

Action to:
• Chief Air Umpire
•
•

PRECEDENCE FOR

Action	Information
OPOP	OPOP

ORIGINAL MESSAGE
REFERS TO ANOTHER MESSAGE

Indentification	Classification

Information to:

1. Chief Umpire.
2. (Aggressor or U. S.) Force Air Umpire.

COMPLETED STRIKE (MISSION) DISPTACH REPORT

ABLE ____________

BAKER ____________

CHARLIE ____________

DOG ____________

EASY ____________

FOX ____________

GEORGE ____________

HOW ____________

ITEM ____________

JIG ____________

SECURITY CLASSIFICATION — SWARMER SECRET

ORIGINATING AGENCY

Symbol	Date-Time Group

AUTHORIZATION

Signature: Name of Airdrome Umpire

Official Title: Airdrome Umpire

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HOSTILE STRIKE DISPATCH REPORT

1. The Hostile Strike Report (MESSAGEFORM WD AGO Form 11-168) will be completed by answering the questions A thru J below and filling in the blanks opposite the same letters on the MESSAGEFORM:

a. Number and type A/C of hostile striking force.

b. Base code and strike number of hostile force.

c. Complete identification of target attacked to include coordinates.

d. Time of the hostile strike.

e. Number of hostiles intercepted by own A/C.

f. Complete identification of unit making the intercept to include Base code and strike number.

g. Losses of own A/C.

h. Estimate damage to hostile A/C in air combat.

i. Estimate damage to hostile A/C by AA fire.

j. Time own damaged A/C will be out of commission.

Incl #2

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MESSAGEFORM	Msg Center No	Transmitting Means	Cryptograph or Clear Text

Calls	Sta Ser	Precedence	Transmission Instructions	Orignater	Date-Time Group
	NR				

Action	Information	Exempt	Operating Signals Group Count
			GR

From: (Originator)

SECURITY CLASSIFICATION

SWARMER SECRET

PRECEDENCE FOR	
Action	Information
OPOP	OPOP

ORIGINAL MESSAGE

REFERS TO ANOTHER MESSAGE	
Indentification	Classification

Action to:

. Chief Air Umpire

.

.

Information to:

1. Chief Umpire.
2. (Aggressor or U. S.) Force Air Umpire.

HOSTILE STRIKE DISPATCH REPORT

ABLE__________

BAKER__________

CHARLIE__________

DOG__________

EASY__________

FOX__________

GEORGE__________

HOW__________

ITEM__________

JIG__________

SECURITY CLASSIFICATION		AUTHORIZATION	
SWARMER SECRET		Signature	Name of Airdrome Umpire
ORIGINATING AGENCY			
Symbol	Date-Time Group	Official Title Airdrome Umpire	Page of

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TACTICAL AIR CONTROL (AND/OR TACTICAL AIR DIRECTION) CENTER DAILY REPORT

1. The Tactical Air Control Center Daily Report (MESSAGEFORM WD AGO Form 11-168) will be completed by answering the questions A thru K below and filling in the blanks opposite the same letters on the MESSAGEFORMS with those answers.

a. Number of total missions, both air support and intercept missions, controlled by the TACC.

b. Number of requests for air support received by the TACC from the JOC.

c. Number of air support missions assigned to TADCs for control.

d. Number of air support missions the TADC assigned to a TACP for control.

e. Number of successful air support missions.

f. Number of intercept missions ordered by the TACC.

g. Number of successful interceptions.

h. Reasons for failure of any air support mission.

i. Reasons for failure of any intercept mission.

j. Number of hours TACC operated.

k. Number of hours the TADC operated.

Incl #3

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MESSAGE FORM	Msg Cen No.	Transmitting means	Cryptograph or clear text
CALLS V / Sta No NR	Precedence	Transmission Instructions	Date-Time Group
Action / Information / Exempt		Operating Signals	Gp Count GR

From: (originator

Security Classification: SWARMER SECRET

Action To: Chief Air Umpire

Precedence for — Action: OPOP — Information: OPOP

Original Message

Refers to another message — Identification — Classification

Information To: 1. Chief Umpire

2. (Aggressor or U. S.) Force Air Umpire

TACTICAL AIR CONTROL (AND/OR TACTICAL AIR DIRECTION) CENTER DAILY REPORT

ABLE__________

BAKER__________

CHARLIE__________

DOG__________

EASY__________

FOX__________

GEORGE__________

HOW__________

ITEM__________

JIG__________

KING__________

~~Security Classification~~ SWARMER SECRET		~~Authorization~~ Signature — Name of Airdrome Umpire	
~~Originating Agency~~ Symbol	Date-Time Gp	Official Title — Airdrome Umpire	Page Of

Inclosure 4
to Appendix 6
Annex "A"
CAU Oper
Plan 1-50

AIRDROME OFFICERS SUMMARY REPORT

The Airdrome Officers Summary Report (MESSAGEFORM WD AGO Form 11-168) will be completed by answering the questions A thru L below and filling in the blanks opposite the same letters on the MESSAGEFORM with their answers:

a. List the Tactical Units on the station.

b. Numbers and type A/C possessed on the station by each unit.

c. Number and type of missions performed by each unit.

d. Number of A/C available for each mission by units.

e. Number and type of missions cancelled and reasons.

f. Personnel and Administration (pertaining to their effect upon the mission of each unit).

g. Intelligence items (pertaining to their effect upon the missions).

h. Operations items (pertaining to their effect upon the mission).

i. Maintenance and supply items (pertaining to their effect upon the missions).

j. Communications items (pertaining to their effect upon the missions).

k. List the subject and the date time groups of all messages dispatched to the Chief Air Umpire during the 24 hour period reported on.

l. Remarks: (List any pertinent items not covered in A thru L. When an item has previously been reported and there has been no change the words "NO CHANGE" will be entered in that space in lieu of repeating the same item).

Incl #4

MESSAGEFORM	MSG CNT No.	Transmitting Means	Cryptograph or Clear Text
Calls / STA. SER. No.	Precedence	Transmission Instructions	DATE-TIME-GROUP
Action / Information / Exempt		Operating Signals	Group Count

SPACE ABOVE FOR SIGNAL CENTER ONLY

FROM (Originator)

Security Classification: SWARMER SECRET

ACTION TO: Chief Air Umpire

Precedence For

Action	Information
OPOP	OPOP

Original Message

Refers to Another Message: Identification . Classification

INFORMATION TO: 1. Chief Umpire

2. (Aggressor or U.S.) Force Air Umpire

AIRDROME OFFICERS SUMMARY REPORT

ABLE__________

BAKER__________

CHARLIE__________

DOG__________

EASY__________

FOX__________

GEORGE__________

HOW__________

ITEM__________

JIG__________

KING__________

LOVE__________

MIKE__________

SECURITY CLASSIFICATION: SWARMER SECRET

AUTHORIZATION — Signature: Name of Airdrome Umpire

ORIGINATING AGENCY

Symbol	Date-Time-Group	Official Title: Airdrome Umpire	Page Of

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Appendix 7
to Annex "A"
CAU Oper
Plan 1-50

24 February 1950

AIR UMPIRE CHECK LIST

INSTRUCTION SHEET

1. To insure that the Air Umpire Group accomplished its mission as outlined, basic check lists have been prepared and are contained in this Appendix. Check Lists are provided for the following:

   a. Tactical Reconnaissance to include liaison type aircraft.

   b. Fighter (Jet).

   c. Troop Carrier.

   d. Light Bombardment.

   e. TACC

   f. TADC

2. In order to secure standardization and to achieve a means of evaluating the performance of participating tactical air units, the USAF, Operational Readiness Tests (ORT's) and the USN Administrative and Material Inspection Forms were used as a guide in preparing the Check Lists. Integrated into these tests and forms were the Training Objectives for each type organization.

3. In accomplishment of the Check Lists, it must be borne in mind that they were designed as a guide to assist in compilation of the final report on the exercise. Accordingly, it is not intended that they restrict or confine the scope of inquiry or observations of the umpire in his effort to determine fairly and accurately the status of a unit that he is observing. If additional items are observed, which are not included in the Check Lists, the items observed, together with manner of performance, may be included under REMARKS in the appropriate sections.

The evaluation of these additional items will be made by the Chief Air Umpire, and appropriate credit given to the particular unit.

4. The attached Check List enumerated in paragraph 1 above are each in two (2) parts. These are "Air Umpire Check List and Score Sheet" and "Air Umpire Final Score Sheet". The FORMAT used for the "Check List and Score Sheet" is similar to the form that is to be used in submitting Final Reports. This will obviously expedite compilation of the Final Reports. Based on job assignment, each umpire with tactical air units will accomplish both the appropriate "Air Umpire Check List and Score Sheet" and the "Air Umpire Final Score Sheet", or applicable portions thereof.

5. The "Air Umpire Check List and Score Sheet" is divided into three (3) main parts. (Part I: Planning Phase, Part II: Training Phase, Part III: Operations Phase). Each Part is sub-divided into five (5) Sections. (A: Personnel and Administration, B: Intelligence, C: Operations, D: Logistics, and E: Communications). Each Section contains one or more items to be checked. Each item has a scoring box beside it on the right hand margin. One half of the scoring box contains a number. This number represents the maximum amount that the umpire may give for that particular item.

6. The umpire will fill in the right hand half of the scoring box <u>ONLY</u> for those items personally checked, evaluated or observed. The remaining item score boxes will remain unscored.

7. When Umpire has completed scoring all possible items (right hand half of scoring box), he will then add up the maximum scores of only those items observed and place that total maximum score in the "MAX" side of the score box opposite each section heading. Then he will add up the unit's score (Umpire's rating) and place that total score in the Unit side of the score box opposite each section heading. This process is repeated for each of the five Sections in each of the three "Parts".

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8. The five Section Maximum scores are then added.

9. Next, total the five (5) section Unit scores and place the total score in the "Unit" side of the Score Box opposite "Total Score for Part I, II, or III as the case may be.

10. Now you are ready to fill in the "Air Umpire Final Score Sheet". In "Summary of Umpires Score" section, take each section separately and add the total score (Max and Unit) for each of the three parts. These total scores are to be placed opposite appropriate Items rated under proper heading (Max Score or Unit Score).

EXAMPLE:

II Part I - Planning Phase

	MAX	UNIT
Section B: Intelligence	15	12
Part II - Training Phase		
Section B: Intelligence	10	5
Part III - Operation Phase		
Section B: Intelligence	20	8
Final Score for Section B Intelligence	45	25

Opposite "Intelligence" under "MAX" Score, place 45

Opposite "Intelligence" under "UNIT" Score, place 25

12. Repeat this procedure for each of the other four (4) sections, add each score separately (Max and Unit), and divide total Max Score by total Unit Score. The result will be the "FINAL SCORE" in percentage.

13. <u>SUBMISSION</u>: Each Tactical Air Umpire will submit one copy of his completed Check Lists and Final Score Sheet to the next higher Air Umpire echelon. The Score Sheets will be consolidated and in turn be forwarded. On arrival at each echelon of command the Check Lists will be utilized in

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preparing the required Final Reports. Individual Squadron/Group Umpire Check List(s) will be attached to the various Final Reports as inclosures when forwarded. The form will be SWARMER SECRET when filled out. The originator will be responsible for having the complete form stamped SWARMER SECRET.

14. SUMMARY:

a. THE IMPORTANCE OF THE SUMMARY CONNOT BE OVER-EMPHASIZED. PROMULGATED HEREIN IS THE CRUX OF THE ENTIRE MANEUVER. HERE IS THE ONE OPPORTUNITY FOR THE AIR UMPIRE TO DEVIATE FROM THE STEROTYPE NUMERICAL RATING SYSTEM AND EXPRESS HIS INDIVIDUAL OPINIONS CLEARLY AND CONCISELY.

b. THE SUMMARY WILL BE THE FOCAL POINT OF ATTENTION FOR ALL REVIEWING AGENCIES. THE EFFICIENCY OF THE UMPIRE, AS WELL AS THE SUCCESS OF THE JOINT MANEUVER, IS REFLECTED BY HOW CAREFULLY AND CONCISELY THE SUMMARY IS PREPARED.

c. EACH PHASE MUST BE SUMMARIZED UPON COMPLETION OF THAT PARTICULAR PHASE. FOR THE PURPOSE OF REPORTING STANDARDIZATION, THE PHASE SUMMARY WILL INCLUDE:

(1) DISCUSSION OF UNUSUAL DIFFICULTIES OR ACCOMPLISHMENTS.

(2) UMPIRE COMMENTS.

(3) UMPIRE RECOMMENDATION(S)

Inclosure 1
to Appendix 7
Annex "A"
CAU Oper
Plan 1-50

FIGHTER

AIR UMPIRE FINAL SCORE SHEET

Date of Report Action Date(s)	Organization
	Location
TO: Chief Air Umpire Hqs, Air Umpire Gp, (Swarmer) Ft Bragg, North Carolina	Service (AF, Navy, Marine, NG)
	COMMAND (Defense) (Invasion)

MISSION OF UNIT: (Indicate number of aircraft participating)

TYPE UNIT	TYPE AIRCRAFT

UMPIRE NAME AND CODE NO.

SUMMARY OF UMPIRES SCORES

ITEMS RATED	MAX SCORES	UNIT SCORES	
Personnel and Administration			
Intelligence			
Operations			
Logistics			
Communications			
TOTALS			FINAL SCORE %
	÷	=	

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FIGHTER

FIGHTER AIR UMPIRE CHECK LISTS (Cont'd)

SUMMARY: (Important)

(Include a summary of each phase listed below with a discussion of unusual difficulties or accomplishments, comments and recommendations.

The reverse of this sheet and/or additional sheets may be utilized for this purpose.

1. Planning Phase

2. Training Phase

3. Operation Phase

FIGHTER

AIR UMPIRE CHECK LIST AND SCORE SHEET

Date________

PART I - PLANNING PHASE

SCORE

Section A: Personnel and Administration — MAX | UNIT

(1) Administration: Check general administration procedure for adaptability to unit mission — 5

(2) Records: Determine overall status of personnel and organization administrative records, as directly effecting the units tactical mission. — 5

(3) Medical: Evaluate apparent status of health of personnel of the unit with respect to accomplishment of its mission. — 5

(4) Mess: Quality, operation, and supervision. Ability to operate in the field. (Comment) — 5

(5) Does unit plan include Chaplain's services? — 5

REMARKS:

Section B: Intelligence — MAX | UNIT

(1) Are Intelligence personnel fully utilized in mission planning? — 5

(2) Are there adequate facilities for operational briefings? — 5

(3) Are briefing personnel familiar with subjects such as:

(a) Importance of target.

(b) Identification of target.

(c) Alternate target.

(d) Ground defenses.

(e) Reporting procedures. — 10

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FIGHTER

Air Umpire Check List (Cont'd)

REMARKS:

Section C: Operations

	MAX	UNIT
(1) Is operations section prepared to sustain unit effective flying? (Ability of unit to schedule 80% of assigned aircraft during the maneuvers).	25	
(2) Does Operations have a plan which adequately covers the Unit phase of maneuver?	15	
(3) Have Air Rescue plans been formulated and coordinated?	5	
(4) Have Air-Defense plans been inaugurated?	10	

REMARKS:

Section D: Logistics

	MAX	UNIT
(1) Has movement and staging preparations for proposed move to combat areas been thoroughly planned?	25	
(2) Evaluate completeness of logistical plan for support of Unit mission.	10	

REMARKS:

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FIGHTER

Air Umpire Check List (Cont'd)

	MAX	UNIT
Section E: Communications		
Evaluate completeness of communications plan for execution of Unit mission	30	

REMARKS:

	MAX	UNIT
Total Score for PART I Planning Phase		

PART II - TRAINING PHASE

	MAX	UNIT
Section A: Personnel and Administration		
(1) Personnel: Observe officers and airmen, both on and off-duty for general military appearance, courtesy, and conduct.	15	
(2) Training Status: Are all personnel adequately trained in primary duty? (Assignment)	10	
(3) Records: Are training records adequate and up-to-date? (Appropriate level)	5	

REMARKS:

	MAX	UNIT
Section B: Intelligence		

(1) Is a training program in effect and does it include:

(a) Escape

(b) Evasion

(c) Survival

(d) Procedure if captured

(e) Security

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FIGHTER

Air Umpire Check List (Cont'd)

(f) Recognition (enemy equipment) | 10 | |

REMARKS:

Section C: Operations | MAX | UNIT |

(1) Number of complete combat crew authorized ________ assigned ________ trained ________ (100% trained = 25 pts) | 20 | |

(2) Has training been conducted under simulated combat conditions? (Prior to maneuver) | 5 | |

(3) List inadequacies in training facilities.

REMARKS:

Section D: Logistics | MAX | UNIT |

(1) Are Supply and Maintenance personnel technically qualified to support unit mission? | 10 | |

(2) Are facilities available for full support of the tactical unit? | 5 | |

REMARKS:

Section E: Communication | MAX | UNIT |

(1) Are communications personnel technically trained in their respective assignments? | 10 | |

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FIGHTER
Air Umpire Check List (Cont'd)

(2) Is there a program in effect to train replacements? [10 |]

(3) Was radio discipline emphasized? [10 |]

REMARKS:

Total Score for PART II Training Phase — MAX [ ] UNIT [ ]

PART III - OPERATIONS PHASE (EXECUTION OF MISSION)

Section A: Personnel and Administration — MAX [ ] UNIT [ ]

(1) Evaluate administrative procedures as applicable to Units tactical mission, including Medical. [10 |]

(2) Coordination with other sections. [5 |]

(3) Were Chaplain's facilities utilized? [5 |]

REMARKS:

Section B: Intelligence — MAX [ ] UNIT [ ]

(1) Briefing and critique should include:

(a) Target material

(b) Combat crew interogation.

(c) Specific essential elements of information. [20 |]

REMARKS:

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FIGHTER

Air Umpire Check List (Cont'd)

	MAX	UNIT
Section C: Operations		
(1) Air Rescue procedures	5	
(2) Counter Air operations	5	
(3) Interdiction operations	5	
(4) Close Tactical air support operations	10	
(5) Escort missions	5	
(6) Air Defense mission (Airdrome defense)	5	
(7) Dive Bombing mission(s)	5	
(8) Sustained operations	20	
(9) Formation flying	10	
(10) Instrument flying		
(a) Individual	5	
(b) Weather penetration by Squadron and flight	10	
(11) Night flying	5	
(12) Emergency procedures	5	
(13) Camera gunnery	5	
(14) Rocketry	5	
(15) Navigation	10	

FIGHTER

Air Umpire Check List (Cont'd)

(16)	High altitude techniques	5
(17)	Ability to work with ground radar control stations	15
(18)	Briefings and critique procedures	10

REMARKS:

Section D: Logistics — MAX | UNIT

(1)	Was refueling and re-arming accomplished with a minimum delay?	15
(2)	Aircraft in commission. Indicate average percentage of combat-ready, assigned aircraft in commission during maneuver. (80% of assigned = 40 pts)	40
(3)	What was the percentage of abortions for each mission?	10
(4)	Organization supply and equipment	
	(a) Evaluate completeness, availability, condition and records, as directly applicable to unit tactical mission.	5
	(b) Adequacy of re-supply.	5
(5)	What maintenance conditions existed which adversely affected the combat effectiveness of the unit. Give adjectival estimate of quality of maintenance, such as superior, good, fair, poor, etc. Superior - 20 points maximum Good - 15 points maximum Fair - 10 points maximum Poor - 5 points maximum	20

FIGHTER

Air Umpire Check List (Cont'd)

REMARKS:

Section E: Communications

	MAX	UNIT
Section E: Communications		
(1) Evaluate ability of unit to efficiently utilize organic communications facilities and equipment.	5	
(2) Was radio discipline observed by the unit.	10	

REMARKS:

	MAX	UNIT
Total Score for PART III Operations Phase		

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Inclosure 2
Appendix 7
Annex "A"
CAU OPER
PLAN 1-50

NAVAL FIGHTER

AIR UMPIRE FINAL SCORE SHEET

Date of Report Action Date (s)	Organization
	Location
TO: Chief Air Umpire Hqs, Air Umpire Gp (SAUG) Ft Bragg, North Carolina	Service (AF, Navy, Army)
	COMMAND (Defense) (Invasion)

MISSION OF UNIT: (Indicate number of aircraft participating)

TYPE UNIT	TYPE AIRCRAFT

UMPIRE NAME AND CODE NO.

SUMMARY OF UMPIRES SCORES

ITEMS RATED	MAX SCORES	UNIT SCORES
Personnel and Administration		
Intelligence		
Operations		
Logistics		
Communications		
TOTALS		

÷ =

Final Score %

0323

HEAVY FIGHTER

Air Umpire Check Lists (Cont'd)

SUMMARY: Important

(Include a summary of each phase listed below with a discussion of unusual difficulties or accomplishments, comments and recommendations. The reverse of this sheet and/or additional sheets may be utilized for this purpose).

1. Planning Phase

2. Training Phase

3. Operations Phase

NAVY FIGHTER

AIR UNIT CHECK LIST AND SCORE SHEET

NAVAL FIGHTER

PART I: Planning Phase.

Section A: Personnel and Administration

Item	SCORE MAX	SCORE UNIT
(1) Administration: Check general administrative procedures for adaptability to unit mission.	5	
(2) Records: Determine over-all status of personnel and organizational administrative records.	5	
(3) Medical: Evaluate apparent status of health of personnel of Unit with respect to accomplishment of its mission.	5	
(4) Mess: Check quality of food, operation and supervision of mess.	5	
(5) Does Unit plan include Chaplains services?	5	

REMARKS:

Section B: Intelligence.

Item	MAX	UNIT
(1) Are Intelligence personnel fully utilized in mission planning?	5	
(2) Are there adequate facilities for operational briefings?	5	
(3) Are briefing personnel familiar with subjects such as: (a) Importance of target. (b) Identification of target (c) Alternate target. (d) Enemy defenses. (e) Reporting procedures.	10	

REMARKS:

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NAVY FIGHTER

AIR UMPIRE CHECK LIST AND SCORE SHEET CONT'D

Section C: Operations. MAX UNIT

(1) Does operations have a plan which adequately covers Unit phase of maneuvers? 20

(2) Have Air Rescue plans been formulated and coordinated? 5

Section D: Logistics. MAX UNIT

(1) Have movement and staging preparations for proposed move to combat areas been thoroughly planned? 25

(2) Completeness of logistical plan for support of Unit mission. 10

(3) Is the maintenance section organized in accordance with current instructions. 10

REMARKS:

Section E: Communications. MAX UNIT

(1) Evaluate completeness of communications plan for execution of Unit mission. 30

REMARKS:

Total Score for Part I Planning Phase MAX UNIT

HEAVY FIGHTER

AIR INSPECTION CHECK LIST AND SCORE SHEET CONT'd

PART II: Training Phase

	MAX	UNIT
Section A: Personnel and Administration		
(1) Personnel: Observe personnel, both on and off duty, for general military appearance, courtesy and conduct.	15	
(2) Training status: Are all personnel adequately trained in their respective ratings? (Assignments)	10	
(3) Records: Are training records adequate and up-to-date? (Appropriate level)	5	

REMARKS:

	MAX	UNIT
Section B: Intelligence		
(1) Is a training program in effect and does it include: (a) Escape (b) Evasion (c) Survival (d) Procedure if captured (e) Recognition (Enemy equipment) (f) Security	10	

	MAX	UNIT
Section C: Operations		
(1) Number of complete combat crews authorized ______ assigned ______ trained ______ (100% trained equals 25 points)	25	
(2) Has training been conducted under simulated combat conditions? (Prior to maneuver)	5	

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NAVY FIGHTER

AIR UMPIRE CHECK LIST AND SCORE SHEET CONT'D

(3) List inadequacies in training facilities.

REMARKS:

Section D: Logistics MAX UNIT

(1) Is there an aggressive, well recorded training program set up to cover all enlisted grades? 10

(2) Do engineering junior officers participate in the maintenance training? 5

REMARKS:

Section E: Communications MAX UNIT

(1) Are communications personnel technically trained in their respective assignment? 10

(2) Is there a program in effect to train replacements? 10

(3) Is radio discipline emphasized? 10

REMARKS:

Total Score for Part II Training Phase MAX UNIT

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NAVY FIGHTER

AIR UNDERWAY CHECK LIST AND SCORE SHEET CONT'D

PART III: Operations Phase (Execution of Mission)

Section A: Personnel and Administration	MAX	UNIT
(1) Evaluate administrative procedures as applicable to Unit tactical mission.	10	
(2) Did the administrative personnel discharge their duties efficiently?	10	
(3) Did they coordinate their activities with other sections?	5	
(4) Were the chaplains facilities utilized?	5	

REMARKS:

Section B: Intelligence	MAX	UNIT
(1) Briefing and critique should include:		
(a) Target material.	5	
(b) Specific essential elements of information.	5	
(c) Reporting of surface vessels.	5	
(d) Intercept.	5	
(e) Reporting procedures.	5	

REMARKS:

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NAVY FIGHTER
AIR UMPIRE CHECK LIST AND SCORE SHEET CONT'D.

Section C: Operations

	MAX	UNIT
(1) Combat Air Patrol	10	
(2) Defense of Carrier or Task Force.	15	
(3) Reconnaissance mission (s).	5	
(4) Counter Air Operations (s).	10	
(5) Mine-laying operation (s)	5	
(6) Torpedo attacks.	5	
(7) Interdiction operation (s)	10	
(8) Deep and/or close support.	10	
(9) Night defense operation (s)	10	
(10) Dive-bombing mission (s)	5	
(11) Sustained operation (s)	15	
(12) Ability to work with surface radar controll stations.	10	
(13) Flying techniques		
(a) Manning aircraft.	5	
(b) Take-off technique.	5	
(c) Formation technique.	5	
(d) Fighter formation.	5	
(e) Navigation.	5	
(f) Defensive maneuver at intercept.	5	
(g) Attack approach procedure (Use of cloud cover, sun, wind, etc.)	5	
(h) Attack timing.	5	
(i) Effectiveness of attack.	5	
(j) Radio discipline.	5	
(k) Formation in landing circle.	5	
(l) Break-up procedure.	5	
(m) Landing technique.	5	
(n) Landing interval.	5	
(o) Weather penetration.	5	
(p) Camera gunnery.	5	
(q) Rocketry.	5	
(r) High altitude techniques.	5	
(s) Emergency procedures.	5	

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NAVY FIGHTER

AIR UMPIRE CHECK LIST AND SCORE SHEET CONT'D

(14) Were briefing and critique procedures satisfactory? [5 |]

Section D: Logistics. MAX [|] UNIT

(1) What was the aircraft availability? (Number completing mission divided by number scheduled. 70% equals 40 points). [40 |]

(2) Are aircraft discrepancies effectively remedied and carefully checked? [10 |]

(3) Was material required for maintenance work ordered promptly and follow-up maintained? [5 |]

(4) Include in remarks any personnel shortages adversely affecting the combat effectiveness of the Unit. Comment, giving adjectival estimate of quality of maintenance.

Superior - 20 points maximum
Good - 15 points maximum
Fair - 10 points maximum
Poor - 5 points maximum [20 |]

REMARKS:

Section E: Communications MAX [|] UNIT

(1) Evaluate ability of Unit to efficiently utilize organic communications facilities and equipment. [5 |]

(2) Was radio discipline observed by unit? [10 |]

REMARKS:

Total Score for Part III Operations Phase MAX [|] UNIT

0331

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Inclosure 3
Appendix 7
Annex "A"
CAU Oper
Plan 1-50

LIGHT BOMBARDMENT

AIR UMPIRE FINAL SCORE SHEET

Date of Report   Action Date(s)   Organization

Location

TO: Chief Air Umpire
Hqs, Air Umpire Gp (Swarmer
Ft Bragg, North Carolina

Service (AF, Navy, Army)

COMMAND (Defense)   (Invasion)

MISSION OF UNIT: (Indicate number of aircraft participating)

TYPE UNIT   TYPE AIRCRAFT

UMPIRE NAME AND CODE NO.

SUMMARY OF UMPIRES SCORES

ITEMS RATED	MAX SCORES	UNIT SCORES	
Personnel and Administration			
Intelligence			
Operations			
Logistics			
Comminications			
TOTALS -			FINAL SCORE %
		≠	=

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Light Bombardment Air Umpire Check Lists (Cont'd)

SUMMARY: (Important)

(Include a summary of each phase listed below with a discussion of unusual difficulties or accomplishments, comments and recommendations.

The reverse of this sheet and/or additional sheets may be utilized for this purpose.

1. Planning phase

2. Training Phase

3. Operation phase

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LIGHT BOMB

AIR UMPIRE CHECK LIST AND SCORE SHEET

LIGHT BOMBERS AND RECONNAISSANCE

Date ____________

	SCORE MAX	UNIT
PART I: Planning Phase		
Section A: Personnel and Administration	MAX	UNIT
(1) Administration: Check general administrative procedures for adaptability to Unit mission.	5	
(2) Records: Determine over-all status of personnel and organizational administrative records.	5	
(3) Medical: Evaluate apparent status of health of personnel of the Unit with respect to accomplishment of its mission.	5	
(4) Mess: Quality, operation, and supervision. Ability to operate in the field.(Comment)	5	
(5) Does unit plan include Chaplain's services?	5	

REMARKS:

	MAX	UNIT
Section B: Intelligence.		
(1) Are intelligence personnel fully utilized in mission planning?	5	
(2) Are there adequate facilities for operational briefings?	5	
(3) Are briefing personnel familiar with subjects such as: (a) Importance of target. (b) Identification of target. (c) Alternate target. (d) Ground defenses. (d) Reporting procedures.	10	

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Air Umpire Check Lists cont'd

REMARKS:

Section C: Operations. MAX | UNIT

	MAX	UNIT
(1) Is operations section prepared to sustain unit effective flying. (Ability of Unit to keep 60% of aircraft operational during the maneuvers)	25	
(2) Does operations have a plan which adequately covers the unit phase of manœuvers?	15	
(3) Have Air-Rescue plans been formulated and coordinated?	5	
(4) Have Air-Defense plans been inaugurated?	10	

REMARKS:

Section D: Logistics MAX | UNIT

	MAX	UNIT
(1) Have movement and staging preparations for proposed move to combat areas been thoroughly planned?	25	
(2) Completeness of logistical plan for support of Unit mission.	15	

0335

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REMARKS:

Section E: Communications

MAX	UNIT

		MAX	UNIT
(1)	Completeness of communications plan for execution of unit mission.	30	
(2)	Completeness of radar countermeasure plan.	5	
(3)	Completeness of radar coverage plan	10	

REMARKS:

Total Score for Part I Planning Phase

MAX	UNIT

PART II - Training Phase

Section A: Personnel and Administration

MAX	UNIT

		MAX	UNIT
(1)	Observe personnel, both on and off duty, for general Military appearance, courtesy and conduct.	15	
(2)	Are all personnel adequately trained in respective ratings (assignments)	10	

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Umpire Check List cont'd

(3) Records: Are training records adequate and up-to-date: (Appropriate level) | 5 | |

REMARKS:

Section B: Intelligence

MAX	UNIT

(1) Is a training program in effect and does it include: | 10 | |

(a) Escape
(b) Evasion
(c) Survival
(d) Procedure if captured
(e) Recognition (Enemy Equipment)
(f) Security

(2) Photo interpretation. | 5 | |

REMARKS:

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LIGHT BOMB

Air Umpire Check List Cont'd

Section C: Operations

	MAX	UNIT
(1) Number of complete combat crew authorized ______ assigned ______ trained ______. (100% trained __ = 25 points.)	25	
(2) Has training been conducted under simulated combat conditions?	5	
(3) List inadequacies in training facilities.		

REMARKS:

Section D: Logistics

	MAX	UNIT
(1) Is there an aggressive, well recorded training program set up to cover all enlisted grades?	10	
(2) Do engineering officers participate in the maintenance training?	5	

REMARKS:

Section E: Communications

	MAX	UNIT
(1) Are communications personnel technically trained in their respective assignments?	10	
(2) Is there a program in effect to train replacements?	20	

LIGHT BOMB

Air Umpire Check List Cont'd

REMARKS:

Total Score for Part II Training Phase

MAX	UNIT

PART III - Operations Phase

Section A: Personnel and Administration.

MAX	UNIT

(1) Evaluate administrative procedure as applicable to Units tactical mission. 10

(2) Coordination with other sections. 5

(3) Were Chaplains facilities utilized? 5

REMARKS:

Section B: Intelligence

MAX	UNIT

(1) Briefing and critique should include:

(a) Target material.

(b) Combat crew interrogation 5

(c) Reporting of surface movements & troops Concentrations. 5

(d) Specific essential elements of information. 5

(e) Photo interpretation. 5

(f) Enemy capabilities. 5 5

0339

LIGHT BOMB

Air Umpire Check List Cont'd

REMARKS:

Section C: Operations	MAX	UNIT
(1) Long range operations.	5	
(2) Bombing visual and radar.	15	
(3) Formation (Take off, assembly, compliance with formation SOP, maintenance of position, defense measures, landing).	15	
(4) Navigation: Dead reckoning, celestial, loran, and radar.	5	
(5) Instrument flying.	10	
(a) Individual proficiency.		
(b) Basic instrument.		
(c) Letdown.		
(d) Emergency procedures.		
(e) Weather penetration.		
(6) Emergency procedures.	5	
(7) Aerial Gunnery.	5	
(8) Cruise control technique.	5	
(9) Mission Planning.	5	
(10) Are there adequate facilities for operational briefings?	5	
(11) Are there effective procedures covering the following:		
(a) Importance of the target.	5	
(b) Identification of the target.	5	
(c) Aiming points.	5	

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Air Umpire Check List Cont'd

Item	Max	Unit
(d) Secondary and targets of opportunity.	5	
(e) Ground defenses.	5	
(f) Fighter reaction.	5	
(g) Reporting procedures.	5	
(12) Sustained unit effective flying - computed in accordance with fraction of 60% of authorized assigned aircraft completing missions. 60% = 40 points.	40	
(13) Air-rescue procedures.	5	
(14) Night flying.	5	
(15) Photo reconnaissance.	5	
(16) Oxygen procedure.	5	

REMARKS:

Item	MAX	UNIT
Section D: Logistics		
(1) Were the refueling and re-arming accomplished with a minimum delay?	15	
(2) Aircraft in commission-indicate average percentage of combat-ready assigned aircraft in commission during maneuver. 60% = 40 points.	40	
(3) Organization supply and equipment.		
(a) Evaluate completeness, availability, condition, and records.	15	
(b) Adequacy of re-supply.	15	

LIGHT BOMB

Air Umpire Check List Cont'd

(4) What maintenance conditions existed which adversely affected the combat effectiveness of the Unit?
Comment: Giving adjectival estimate of quality of maintenance, such as superior, good, fair, poor, etc.

Superior - 20 points maximum
Good - 15 points maximum
Fair - 10 points maximum
Poor - 5 points maximum

REMARKS: | 20 | |

Section E: Communications. MAX UNIT | | |

(1) Evaluate ability of the unit to efficiently utilize organic communications facilities and equipment. | 5 | |

(2) Was radio discipline observed by the unit? | 10 | |

(3) Evaluate the adequacy of the communications system as directly affecting the unit's tactical efficiency.

REMARKS: | 10 | |

Total Score for Part III
Operations Phase | | |

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Inclosure 4 TROOP CARRIER
Appendix 7 to Annex "A"
CAU Operation Plan 1-50

AIR UMPIRE FINAL SCORE SHEET

Date of Report Action Date (s)	Organization
TO: Chief Air Umpire Hqs, Air Umpire Gp (Swarmer) Ft Bragg, North Carolina	Location Service (AF, Navy, Army) COMMAND (Defense) (Invasion)

MISSION OF UNIT: (Indicate Number of Aircraft Participating)

TYPE UNIT	TYPE AIRCRAFT

UMPIRE NAME AND CODE NO.

SUMMARY OF UMPIRES SCORES

ITEMS RATED	MAX SCORES	UNIT SCORES	
Personnel and Administration			
Intelligence			
Operations			
Logistics			
Communications			
TOTALS			FINAL SCORE %
			=

0343

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TROOP CARRIER

Troop Carrier Air Umpire Check Lists (Cont'd)

SUMMARY: (Important)

(Include a summary of each phase listed below with a discussion of unusual difficulties or accomplishments, comments and recommendations.

The reverse side of this sheet and/or additional sheets may be utilized for this purpose.)

1. Planning Phase

2. Training Phase

3. Operation Phase

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AIR UMPIRE CHECK LIST AND SCORE SHEET

TROOP-CARRIER

Date____________

PART I - Planning Phase

Section A: Personnel and Administration — MAX | UNIT

SCORE: MAX | UNIT

		MAX	UNIT
(1)	Administration and Records: Is the unit capable of efficient administration and maintenance of records, operating either as an independent squadron or as a part of a task force, wing or group?	10	
(2)	Medical: Evaluate apparent status of health of personnel of the Unit with respect to accomplishment of its mission.	5	
(3)	Does Unit plan include Chaplains' services?	5	
(4)	Mess: Quality, operation and supervision. Ability to operate in the field.	5	

REMARKS:

Section B: Intelligence — MAX | UNIT

		MAX	UNIT
(1)	Are Intelligence personnel fully utilized in mission planning?	5	
(2)	Are there adequate facilities for operational briefings?	5	
(3)	Are briefing personnel familiar with subjects such as: (a) Identification of drop zone (b) Importance of target (c) Alternate target (d) Enemy capabilities (e) Reporting procedures	10	

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TROOP CARRIER

Air Umpire Check List and Score Sheet Cont'd

REMARKS:

Section C: Operations

MAX	UNIT

(1) Is operations section prepared to sustain unit effective flying? (Ability of unit to schedule 75% of assigned aircraft operational during the maneuvers?) — 25

(2) Does operations have a plan and a standing operating procedure which adequately covers the unit phase of maneuvers? — 15

(3) Was the DZ selected jointly with the commander of the Airborne Unit? — 5

(4) Was there a mutual exchange of liaison personnel between troop carrier and Airborne Units? — 5

(5) Was pertinent photo coverage requested? (DZ, LZ, Routes) — 5

(6) Was a joint Command Post established at the departure base? — 5

(7) Were joint-planning conferences held? — 5

REMARKS:

Section D: Logistics

MAX	UNIT

(1) Has movement and staging preparations for proposed move to combat area been thoroughly planned? — 25

(2) Do plans provide for aerial re-supply of ground units? If so, have the plans been coordinated with other sections? — 5

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TROOP CARRIER

Air Umpire Check List and Score Sheet Cont'd

(3) Evaluate completeness of logistical plan for support of unit mission(s) — 10

REMARKS:

Section E: Communications — MAX | UNIT

(1) Evaluate completeness of communications plan for execution of unit mission. — 30

(2) Has the communications plan been properly coordinated with other units? — 10

REMARKS:

TOTAL SCORE FOR PART I PLANNING PHASE

PART II - Training Phase

Section A: Personnel and Administration — MAX | UNIT

(1) Personnel: Observe officers and airmen, both on and off-duty, for general military appearance, courtesy and conduct. — 15

(2) Training Status: Are all personnel adequately trained in primary duty? (Assignment) — 10

(3) Records: Are training records adequate and up-to-date? (Appropriate level) — 5

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TROOP CARRIER

Air Umpire Check List and Score Sheet Cont'd

REMARKS:

Section B: Intelligence

MAX	UNIT

(1) Whether a training program is in effect and includes:

(a) Escape
(b) Evasion
(c) Survival
(d) Procedure if captured
(e) Recognition training (Enemy equip)
(f) Security

10	

REMARKS:

Section C: Operations

MAX	UNIT

(1) Number of complete combat crews
Authorized______ Assigned______ Trained______

20	

(2) Has training been conducted under simulated combat conditions?

5	

(3) List inadequacies in training facilities.

(4) Successful rehearsals for maneuvers observed by umpire to be evaluated at 5 points maximum each (Not more than three)

15	

REMARKS:

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TROOP CARRIER

Air Umpire Check List and Score Sheet Cont'd

Section D: Logistics

MAX	UNIT

Are supply and maintenance personnel technically qualified to support unit missions? | 10 | |

REMARKS:

Section E: Communications

MAX	UNIT

(1) Are communications personnel technically trained in their respective assignments? | 10 | |

(2) Is there a program in effect to train replacements? | 15 | |

(3) Was radio discipline emphasized? | 5 | |

REMARKS:

TOTAL SCORE FOR PART II TRAINING PHASE

MAX	UNIT

PART III - Operations Phase (Execution of Mission)

Section A: Personnel and Administration

MAX	UNIT

(1) Evaluate administrative procedures as applicable to unit tactical mission. | 10 | |

(2) Coordination with other sections. | 5 | |

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TROOP CARRIER

Air Umpire Check List and Score Cont'd

REMARKS:

Section B: Intelligence

	MAX	UNIT
Section B: Intelligence		
(1) Briefing and critique should include:		
(a) Target material	5	
(b) Combat crew interrogation	5	
(c) Specific essential elements of information	5	
(2) Completeness of crew interrogation	5	

REMARKS:

Section C: Operations

	MAX	UNIT
Section C: Operations		
(1) Coordination of air movement with other air, ground and naval forces.	20	
(2) Pathfinder procedures.	5	
(3) Selection of drop zone	5	
(4) Selection of routes and formation	5	
(5) Briefings	5	
(6) Were aircraft spotted in sufficient time for Airborne troops to accomplish necessary loading?	5	
(7) Was the number of aircraft in accordance with standard operating procedures?	5	
(8) Were spare aircraft conveniently parked?	5	

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TROOP CARRIER

Air Umpire Check List and Score Sheet cont'd

(9) Aircraft operation procedures to include marshalling on the ground and assembly in the air, formation, timing, altitude, airspeed, etc.	20	
(10) Navigation.	10	
(11) Slwo-down procedures.	5	
(12) Jump procedure (to include speed over DZ, jump signal, and altitude over DZ.)	20	
(13) Delivery of paratroopers on schedule to the designated DROP ZONE (DZ)	40	
(14) Delivery of re-supplies on schedule to a designated DZ.	10	
(15) Movement and staging operations to and from the Theater of Operations.	10	
(16) Were Chaplain's facilities utilized?	5	

REMARKS:

	MAX	UNIT
Section D: Logistics		
(1) Was re-fueling and re-spotting accomplished efficiently and with a minimum of delay?	15	
(2) Aircraft in commission indicate average percentage of combat ready assigned, in commission, during maneuvers. (75% equals 40 points)	40	
(3) What was the percentage of aircraft abortions for each mission?	10	
(4) Organization supply and equipment:		
(a) Evaluate completeness, availability, condition and records.	15	
(b) Adequacy of re-supply.	15	

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TROOP CARRIER

Air Umpire Check List Score Sheet Cont'd

(5) What maintenance conditions existed which adversely affected the combat effectiveness of Unit? Comment; giving adjectival estimate of quality of maintenance such as superior, good, fair, poor, etc.

Superior - 20 points maximum
Good - 15 points maximum
Fair - 10 points maximum
Poor - 5 points maximum

20	

REMARKS:

Section E: Communications

MAX	UNIT

(1) Evaluate ability of unit to efficiently utilize organic communications facilities and equipment.

5	

(2) Was radio discipline observed by Unit?

5	

(3) Evaluate the adequacy of the communication system as directly effecting the Unit's tactical efficiency.

15	

TOTAL SCORE FOR PART III
OPERATIONS PHASE

MAX	UNIT

REMARKS:

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TACTICAL RECONNAISSANCE

Inclosure 5
Appendix 7
Annex "A"
CAU Oper
Plan 1-50

AIR UMPIRE FINAL SCORE SHEET

Date of Report Action Date(s)	Organization
	Location ________
TO: Chief Air Umpire Hqs, Air Umpire Gp (Swarmer) Ft Bragg, North Carolina	Service (AF, Navy, Marine, NG) COMMAND (Defense) (Invasion)

MISSION OF UNIT: (Indicate number of aircraft participating)

TYPE UNIT	TYPE AIRCRAFT

UMPIRE NAME AND CODE NO.

SUMMARY OF UMPIRES SCORES

ITEMS RATED	MAX SCORES	UNIT SCORES	
Personnel and Administration			
Intelligence			
Operations			
Logistics			
Communications			FINAL SCORE%
TOTALS		÷	=

0353

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Tactical Reconnaissance Air Umpire Check Lists (Cont'd)

SUMMARY: (Important)

(Include a summary of each phase listed below with a discussion of unusual difficulties or accomplishments, comments and recommendations. The reverse of this sheet and/or additional sheets may be utilized for this purpose.

1. Planning Phase

2. Training Phase

3. Operations Phase

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TACTICAL RECONNAISSANCE

AIR UMPIRE CHECK LIST AND SCORE SHEET

PART I: Planning

	MAX	UNIT
Section A: Personnel and Administration		
(1) Administration: Check general administrative procedures for adaptability to unit's tactical mission.	5	
(2) Records: Determine over-all status of personnel, organizational, and administrative records directly affecting units tactical mission.	5	
(3) Medical: Evaluate apparent status of health of personnel of the unit with respect to accomplishment of its mission.	5	
(4) Mess: Quality, operation, and supervision. Ability to operate in the field. Comment.	5	
(5) Does Unit plan include Chaplains Services?	5	

REMARKS:

	MAX	UNIT
Section B: Intelligence.		
(1) Are Intelligence personnel fully utilized in mission planning?	5	
(2) Are there adequate facilities for operational briefings?	5	

(3) Are briefing personnel familiar with subjects such as:

(a) Importance of target
(b) Identification of target

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(c) Alternate target
(d) Ground defenses
(e) Reporting procedures [10 |]

(4) Are there adequate facilities for photo processing? [5 |]

REMARKS:

Section C; Operations. [MAX | UNIT]

(1) Is operations section prepared to sustain unit effective flying? (Ability of section to schedule 70% of aircraft during the maneuvers.) [25 |]

(2) Does Operations have a plan which adequately covers the Unit phase of maneuvers? [15 |]

(3) Have Air-Rescue plans been formulated and co-ordinated? [5 |]

(4) Have Air-Defense plans been inaugurated? [10 |]

REMARKS?

Section D: Logistics, [MAX | UNIT]

(1) Has movement and staging preparations for proposed move to combat areas been thoroughly planned? [25 |]

(2) Completeness of logistical plan for support of unit tactical Mission. [10 |]

REMARKS:

Section E: Communications.

	MAX	UNIT
(1) Evaluate completeness of communications plan for execution of unit mission.	30	
(2) Has Communications plan been properly coordinated with other units?	15	
(3) Adequate radar countermeasure plan.	5	

REMARKS:

	MAX	UNIT
Total Score for Part I Planning Phase		

PART II: Training Phase

Section A: Personnel and Administration.

	MAX	UNIT
(1) Personnel: Observe officers and airmen, both on and off-duty for general military appearance, courtesy, and conduct.	15	
(2) Training Status: Are all personnel adequately trained in primary duty? (Assignment)	10	
(3). Records: Are training records adequate and up-to-date? (Appropriate level)	5	

TACTICAL RECONNAISSANCE

Air Umpire Check List (Cont'd)

REMARKS:

Section B: Intelligence.

MAX	UNIT

(1) Is a training program in effect and does it include:

(a) Escape
(b) Evasion
(c) Survival
(d) Procedure if captured
(e) Recognition (Enemy equipment)

MAX	UNIT
10	

REMARKS:

Section C: Operations.

MAX	UNIT

(1) Number of complete combat crew authorized ______ assigned ______ trained ______ (100% trained = 25 pts) [25 |]

(2) Has training been conducted under simulated combat conditions? (Prior to maneuvers) [5 |]

(3) Has specialized training been conducted to include: (Prior to maneuvers)

(a) Visual reconnaissance.
(b) Day/night photo reconnaissance.
(c) Radar countermeasure operation.
(d) Artillery adjustment operations.
(e) Photo technical services.

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(4) List inadequacies in training facilities.

REMARKS:

Section D: Logistics. MAX UNIT

(1) Are S-4 personnel technically qualified to support unit mission? 10

(2) Are S-4 personnel technically qualified to support photographic phase of unit mission? 5

REMARKS:

Section E: Communications. MAX UNIT

(1) Are communications personnel technically trained in their respective assignments? 5

(2) Is there a program in effect to train replacements? 10

(3) Was radio discipline emphasized? 5

REMARKS:

Total Score Part II, Training Phase MAX UNIT

TACTICAL RECONNAISSANCE

PART III: Operations

Section A: Personnel and Administration

	MAX	UNIT
Section A: Personnel and Administration		
(1) Evaluation administrative procedures as applicable to Units tactical mission.	10	
(2) Coordination with other sections.	5	
(3) Were Chaplains facilities utilized?	5	

REMARKS:

Section B: Intelligence.

	MAX	UNIT
Section B: Intelligence.		
(1) Briefing and critique should include:		
(a) Target material	5	
(b) Combat crew interrogation	5	
(c) Specific essential elements of information:	5	
(d) Ground defenses	5	
(e) Fighter reaction	5	
(f) Photo interpretation	10	

REMARKS:

	MAX	UNIT
Section C: Operations.		
(1) Air Rescue procedures	5	
(2) Counter Air operations	5	

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TACTICAL RECONNAISSANCE

Air Umpire Check List (Cont'd)

		MAX	UNIT
(3)	Airdrome defense mission.	5	
(4)	Sustained unit effective flying (Utilizing an average 70% of aircraft combat operational during maneuver).	20	
(5)	Photographic Reconnaissance (proficiency in pin-point, strip and area coverage).	10	
(6)	Proficiency in removing film from aircraft, processing and printing within one (1) hour.	10	
(7)	Visual Reconnaissance (proficiency in providing visual information day and night to include artillery adjustment).	5	
(8)	Navigation (indivudual aircraft accuracy, day and night utilizing electronic aids and dead reckoning).	10	
(9)	Instrument flying (Individual proficiency, basic instruments, letdown procedures, weather penetration).	10	
(10)	Briefing and critique (Procedures, adequacy, control of crews).	10	
(11)	Emergency procedures (Action of crews under emergency conditions).	5	
(12)	Radar countermeasure operations.	5	
(13)	Mapping photography.	5	
(14)	Weather reconnaissance mission.	5	

REMARKS:

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TACTICAL RECONNAISSANCE

AIR UMPIRE CHECK LIST (CONT'D)

Section C: Operations (Liaison) (For use when applicable)

	MAX	UNIT
Section C total		
(1) Courier mission.	5	
(2) Emergency evacuation missions.	5	
(3) Artillery adjustment missions.	15	
(4) Emergency resupply mission.	5	
(5) Limited reconnaissance missions.	10	
(6) Personnel ferrying missions.	5	

REMARKS:

Section D: Logistics.

	MAX	UNIT
Section D total		
(1) Was refueling and re-arming accomplished with minimum delay?	15	
(2) Aircraft in commission. Indicate average percentage of combat-ready, assigned aircraft in commission during maneuver. (70% of assigned = 40 pts)	40	
(3) What was the percentage of abortions for each mission?	10	
(4) Organization supply and equipment:		
(a) Evaluate completeness, availability, condition, and records, as directly effecting the units and actual mission.	5	
(b) Adequacy of re-supply.	5	

(5) What maintenance conditions existed which adversely effected the combat effectiveness of the unit. Comment giving adjectival estimate of quality of maintenance, such as superior, good, fair, poor, etc.

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TACTICAL RECONNAISSANCE

Air Umpire Check List (Cont'd)

Superior - 20 points maximum
Good - 15 points maximum
Fair - 10 points maximum
Poor - 5 points maximum

MAX	UNIT
20	

REMARKS:

Section E: Communications.

MAX	UNIT

(1) Evaluation ability of unit to efficiently utilize organic communications facilities and equipment. Comment

MAX	UNIT
5	

(2) Were visual signals employed?

MAX	UNIT
5	

(3) Was Radio discipline observed by Unit?

MAX	UNIT
10	

REMARKS:

Total Score for Part III Operations Phase

MAX	UNIT

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Inclosure 7
Appendix 7
Annex "A"
CAU Oper
Plan 1-50

TACTICAL AIR DIRECTION CENTER

AIR UMPIRE FINAL SCORE SHEET

Date of Report | Action Date(s) | Organization

Location

TO: Chief Air Umpire
Hqs, Air Umpire Gp (Swarmer)
Ft Bragg, North Carolina

Service (AF, Navy, Army)

COMMAND (Defense) (Invasion)

MISSION OF UNIT:

TYPE UNIT

UMPIRE NAME AND CODE NO.

SUMMARY OF UMPIRES SCORES

ITEMS RATED	MAX SCORES	UNIT SCORES
Personnel and Administration		
Operations		
Logistics		
Communications		
TOTALS		

FINAL SCORE %

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TACTICAL AIR DIRECTION CENTER

SUMMARY: (Important)
(Include a summary of each phase listed below with a discussion of unusual difficulties or accomplishments, comments and recommendations. The reverse of this sheet and/or additional sheets may be utilized for this purpose).

1. Planning Phase

2. Training Phase

3. Operations Phase

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TACTICAL AIR DIRECTION CENTER
AIR UMPIRE CHECK LIST AND SCORE SHEET

TACTICAL AIR DIRECTION CENTER

Date________

SCORE
MAX UNIT

PART I: Planning Phase

Section A: Personnel and Administration — MAX | UNIT

	MAX	UNIT
(1) Administration: Check general administrative procedures for adaptability to unit mission.	5	
(2) Records: Determine over-all status of personnel and organizational administrative records.	5	
(3) Medical: Evaluate apparent status of health of personnel of the unit with respect to accomplishment of its mission.	5	
(4) Mess: Quality, operation, and supervision. Ability to oper te in the field. (Comment)	5	
(5) Does unit plan include Chaplain's services?	5	

REMARKS:

Section B: Operations. — MAX | UNIT

	MAX	UNIT
(1) Is Unit prepared to sustatin effective radar operations for control of assigned air-space (Ability of Unit to operate continuously, 24 hours daily, for at least 90% of the time during the maneuver)	20	
(2) Is unit prepared to sustain effective communications for control of assigned air-space (Ability of unit to maintain communications channels and electronic aids to air navigation operational 100% of the time during the maneuver)	20	
(3) Does operations plan adequately cover the unit phase of maneuvers to include plans for movement of unit forward?	20	
(4) Have Security plans been inaugurated?	15	

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TACTICAL AIR DIRECTION CENTER

REMARKS:

Section C: Logistics.	MAX	UNIT
(1) Have movement and staging preparations for proposed move to combat areas been thoroughly planned.	15	
(2) Completeness of logistics plan for support of unit mission.	10	

REMARKS:

Section D: Communications.	MAX	UNIT
(1) Completeness of communications plan for execution of unit mission.	15	
(2) Completeness of radar coverage and control plan.	10	

REMARKS:

Total Score for PART I Planning Phase	MAX	UNIT

PART II - Training Phase

Section A: Personnel and Administration.	MAX	UNIT
(1) Observe personnel both on and off duty, for general military appearance, courtesy and conduct.	15	
(2) Are all personnel adequately trained in respective ratings (Assignments)?	10	
(3) Records: Are training records adequately and up-to-date? (Appropriate level)	5	

TACTICAL AIR DIRECTION CENTER

REMARKS:

Section B: - Operations:

	MAX	UNIT
(1) Number of personnel authorized ________ assigned ________ trained ________. (100% trained = 25 points)	25	
(2) Has training been conducted under simulated combat conditions?	5	
(3) Is OJT program effective?	15	
(4) Is schedule and plan maintained with a view toward bringing the unit to 100% combat effectiveness?	10	
(5) List inadequacies in training facilities.		

REMARKS:

Section C: Logistics:

	MAX	UNIT
Are supply and maintenance personnel technically trained in their respective assignments?	25	

REMARKS:

Section D: Communications:

	MAX	UNIT
(1) Are communications and radar personnel technically trained in their respective assignments?	20	
(2) Is there a program in effect to train replacements?	20	

REMARKS:

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TACTICAL AIR DIRECTION CENTER

	MAX	UNIT
Total Score for PART II Training Phase		

PART III - Operations Phase

	MAX	UNIT
Section A: Personnel and Administration:		
(1) Evaluate administrative procedures as applicable to units tactical mission.	10	
(2) Coordination with other sections.	5	
(3) Were Chaplain's facilities utilized?	5	

REMARKS:

	MAX	UNIT
Section B: Operations:		
(1) Ability of unit to efficiently operate organic radar and IFF equipment, reporting data obtained within SOP time limits.	40	
(2) Ability of unit to clearly present a continuous and timely presentation of the air picture.	25	
(3) Ability of unit to utilize air information to control combat forces.	25	
(4) Efficiency of Controllers to plan, control and direct air operations of combat forces.	40	
(5) Coordination with other units.	5	
(6) Sustained effective radar operations and communications for control of assigned air-space (computed in accordance with fraction of 90% for radar and 100% for communications effective time on 24 hours basis. Equal weight given to both radar and communications.)	40	
(7) Ability of unit to safeguard equipment and personnel.	10	

REMARKS:

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TACTICAL AIR DIRECTION CENTER

	MAX	UNIT
Section C: Logistics:		
(1) Sustained effective in-commission time of assigned equipment (Computed in accordance with fraction of 90% for radar and 100% for communications effective in-commission time on 24-hour basis).	35	
(2) Organization supply and equipment:		
(a) Evaluate completeness, availability conditions and records.	10	
(b) Adequacy of re-supply.	10	
(3) Adjectival estimate of quality of maintenance to include assembly and disassembly of equipment as follows: Superior - 20 points maximum Good - 15 points maximum Fair - 10 points maximum Poor - 5 points maximum	20	

REMARKS:

	MAX	UNIT
Section D: Communications:		
(1) Evaluate ability of unit to effectively utilize organic communication equipment.	40	
(2) Was radio discipline observed?	10	
(3) Evaluate the adequacy of the communications system as directly affecting the units tactical efficiency.	20	

REMARKS:

	MAX	UNIT
Total Score for PART III Operation Phase		

0370

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Inclosure 6
Appendix 5
Annex "A"
CAU Oper
Plan 1-50

TACTICAL AIR CONTROL CENTER

AIR UMPIRE FINAL SCORE SHEET

Date of Report	Action Date (s)	Organization
		Location
TO: Chief Air Umpire Hqs, Air Umpire Gp (Swarmer) Ft Bragg, North Carolina		Service (AF, Navy, Army)
		COMMAND (Defense) (Invasion)

MISSION OF UNIT:

TYPE UNIT

UMPIRE NAME AND CODE NO.

SUMMARY OF UMPIRE SCORES

ITEMS RATED	MAX SCORES	UNIT SCORES
Personnel and Administration		
Operations		
Logistics		
Communications		
TOTALS		FINAL SCORE %

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TACTICAL AIR CONTROL CENTER

SUMMARY: Important

(Include a summary of each phase listed below with discusion of unusual difficulities or accomplishments, comments and recommendation.

The reverse of this sheet and/or additional sheets may be utilized for this purpose).

1. Planning Phase

2. Training Phase

3. Operation Phase

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TACTICAL AIR CONTROL CENTER

AIR UMPIRE CHECK LIST AND SCORE SHEET

Date ____________

PART I: Planning Phase

	MAX	UNIT	SCORE MAX	SCORE UNIT
Section A: Personnel and Administration				
(1) Administration: Check general administrative procedures for adaptability to unit mission.			15	
(2) Records: Determine over-all status of personnel and organization administration records, as directly effecting the units tactical mission.			10	
(3) Medical: Evaluate apparent status of health with respect to accomplishment of its mission.			5	
(4) Mess: Quality, operation and supervision ability to operate in the field comment.			5	
(5) Does Unit plan include Chaplains services?			5	

REMARKS:

	MAX	UNIT	SCORE MAX	SCORE UNIT
Section B: Operation.				
(1) Presentation of Air Situation: Ability of Unit to clearly present a continuous and timely representation of the air picture.			20	
(2) Communications operation: Ability of Unit to efficiently utilize organic communication facilities and equipment.			15	
(3) Security: Ability of Unit to safeguard equipment and personnel.			15	

REMARKS:

0373

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TACTICAL AIR CONTROL CENTER

Section C: Logistics

	MAX	UNIT
(1) Have movement and staging preparations for proposed move to combat area been thoroughly planned?	20	
(2) Evaluate completeness of ogistical plan for support of Unit Mission.	20	

REMARKS:

Section D: Communications.

	MAX	UNIT
Evaluate completeness of communications plan for execution of Unit Mission.	20	

REMARKS:

	MAX	UNIT
Total Score for Part I Planning Phase		

PART II - Training Phase

Section A: Personnel and Administration:

	MAX	UNIT
(1) Personnel: Observe officers and airmen, both on and off duty, for general military appearance, courtesy, and conduct.	10	
(2) Training Status: Are all personnel adequately [illegible] in primary duty? (Assignment)	15	
(3) [illegible] training records adequate and up-to-date? (Appropriate Level)	15	

REMARKS:

Section B: Operations.

MAX	UNIT

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TACTICAL AIR CONTROL CENTER

(1)	On-the-job Training: Is program effective?	20
(2)	Has training been conducted under simulated combat conditions? (Prior to maneuver)	15
(3)	List inadequacies in training facilities (percentage)	10
(4)	Security: Ability of unit to safeguard equipment and personnel.	10

REMARKS:

Section C: Logistics: MAX | UNIT

(1)	Are maintenance and supply personnel technically qualified to support unit mission?	20
(2)	Are facilities available for full support of the tactical unit?	20

REMARKS:

Section D: Communications: MAX | UNIT

(1)	Are communications personnel technically trained in their respective assignments?	15
(2)	Is there a program in effect to train replacements?	15
(3)	Is radio discipline emphasized?	10

REMARKS:

Total Score for Part II Training Phase MAX | UNIT

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TACTICAL AIR CONTROL CENTER

PART III: Operations Phase (Execution of Mission)

Section A: Personnel and Administration: MAX UNIT

(1) Evaluate administrative procedure as applicable to unit's tactical mission, including medical. 25

(2) Coordination with other sections. 20

(3) Were Chaplin's facilities utilized? 5

REMARKS:

Section B: Operations. MAX UNIT

(1) Can unit clearly present a continuous and timely representation of the air picture? 20

(2) Ability of unit to identify all friendly aircraft through knowledge of flight plans radar, and other related information. 25

(3) Ability of unit to utilize information of air situation to effectively employ fighter aircraft and AAA. 20

(4) Is unit capable of controlling the air space above its assigned area of responsibility? 25

(5) Security: Ability of unit to safeguard communications equipment, and personnel. 15

REMARKS:

Section C: Logistics. MAX UNIT

(1) Is unit capable of moving forward, orderly and efficiently without losing control of the air at the same rate the supported Ground Forces advance in battle situation. 30

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(2) Evaluate completeness, availability conditions, and records of organizational supplies and equipment. [20 |]

REMARKS:

Section D: Communications: MAX UNIT [|]

(1) Evaluate ability of unit to efficiently utilize organic communications facilities and equipment. [30 |]

(2) Was radio discipline observed by the unit? [|]

REMARKS:

Total Score for Part III Operations Phase — MAX UNIT [|]

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Inclosure 8
Appendix 7
Annex "A"
CAU Oper
Plan 1-50

SIGNAL BATTALION

AIR UMPIRE FINAL SCORE SHEET

Date of Report Action Date(s)

Organization

Location

TO: Chief Air Umpire
Hqs, Air Umpire Gp (Swarmer)
Ft Bragg, North Carolina

Service (AF, Navy, Marine, NG)

COMMAND (Defense) (Invasion)

MISSION OF UNIT:

TYPE UNIT

UMPIRE NAME AND CODE NO.

SUMMARY OF UMPIRES SCORES

ITEMS RATED	MAX SCORES	UNIT SCORES
Personnel and Administration		
Operations		
Logistics		
Communications		
TOTALS		FINAL SCORE %

0378

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SIGNAL BATTALION

SUMMARY: Important
(Include a summary of each phase listed below with a discussion of unusual difficulties or accomplishments, comments and recommendations. The reverse of this sheet and/or additional sheets may be utilized for this purpose).

1. Planning Phase

2. Training Phase

3. Operations Phase

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SIGNAL BATTALION

AIR UMPIRE CHECK LIST AND SCORE SHEET

SIGNAL BATTALION

Date ____________________

	SCORE	
	MAX	UNIT
PART I: Planning Phase		
Section A: Personnel and Administration		
(1) Administration: Check general administration procedures for adaptability to unit mission.	15	
(2) Records: Determine overall status of personnel and organizational administration records..	10	
(3) Medical: Evaluate apparent status of health of personnel of the unit with respect to accomplishment of its mission.	5	
(4) Mess: Quality, operation and supervision. Ability to operate in the field. Comment	5	

REMARKS:

	MAX	UNIT
Section B: Operations		
(1) Is unit prepared to sustain effective communications for the assigned mission? (Ability of Unit to maintain communications for the T.ACG. 100% of the time during the maneuver).	30	
(2) Does operations plan adequately cover the Unit phase of maneuvers to include plans for movement of unit forward?	10	
(3) Have Security plans been inaugurated?	10	

REMARKS:

	MAX	UNIT
Section C: Logistics		

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SIGNAL BATTALION

(1) Have movement and staging preparations for proposed move to combat areas been thoroughly planned? | 10 | |

(2) Completeness of logistics plan for support of unit mission. | 10 | |

REMARKS:

	MAX	UNIT
Section D: Communications:		

(1) Completeness of communications plan for execution of unit mission. | 10 | |

(2) Completeness of communications coverage and control plan. | 10 | |

REMARKS:

	MAX	UNIT
Total Score for PART I Planning Phase		

PART II Training Phase

	MAX	UNIT
Section A: Personnel and Administration:		

(1) Personnel: Observe officers and airmen, both on and off duty, for general military appearance, courtesy, and conduct. | 5 | |

(2) Training Status: Are all personnel adequately trained in primary duty? (assignment) | 5 | |

(3) Records: Are training records adequate and up to date? (Appropriate level) | 5 | |

REMARKS:

0381

SIGNAL BATTALION

Section B: Operations

MAX	UNIT

	MAX	UNIT
(1) On the Job Training: Is program effective?	10	
(2) Has training been conducted under simulated combat conditions? (Prior to maneuver)	10	
(3) Security: Ability of unit to safeguard communications, equipment, and personnel.	10	
(4) List inadequacies in training facilities.	5	

REMARKS:

Section C: Logistics:

MAX	UNIT

	MAX	UNIT
Are S - 4 personnel technically qualified to support unit mission.	10	

REMARKS:

Section D: Communications:

MAX	UNIT

	MAX	UNIT
(1) Are communication personnel technically trained in their respective assignments?	20	
(2) Is there a program in effect to train replacements?	10	
(3) Are all routine requirements of the unit covered by SOP or COI?	15	

REMARKS:

0382

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SIGNAL BATTALION

Total Score for PART II Training Phase

MAX	UNIT

PART III Operations Phase

Section A: Personnel and Administration:

MAX	UNIT

(1) Evaluate administrative procedure as applicable to unit's tactical mission, including medical. — 10

(2) Coordination with other sections. — 5

(3) Were Chaplain's facilities utilized? — 5

REMARKS:

Section B: Operations

MAX	UNIT

(1) Are all personnel familiar with established SOP or SOI? — 15

(2) Is the communications plan of the next higher headquarters adequate to make provisions for all requirements of the unit? — 10

(3) Is the unit communication plan adequate to support the mission? — 15

(4) Ability of the unit to perform its assigned mission under combat conditions. — 15

(5) Ability of unit to safeguard communications, equipment, and personnel. — 10

REMARKS:

Section C: Logistics

MAX	UNIT

(1) Is unit capable of moving forward, orderly and efficiently, at the same rate the supported Ground Forces advance in battle situation? — 15

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SIGNAL BATTALION

(2) Does TO&E provide sufficient equipment to perform the mission? | 10 | |

(3) Evaluate completeness, availability, conditions, and records of organizational supplies and equipment. | 10 | |

REMARKS:

Section D: Communications:

MAX	UNIT

(1) Evaluate ability of unit to efficiently utilize organic communications facilities and equipment. | 10 | |

(2) Are adequate publications on hand? | 5 | |

(3) Does the communication plan provide for an alternate method of communication? (Whether alternate method applied) | 5 | |

REMARKS:

Total Score for PART III Operations Phase

MAX	UNIT

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Annex "B"
CAU Oper
Plan 1-50

AIR UMPIRE SECTION (SWARMER)
Ft Bragg, North Carolina

COMMUNICATIONS

1. MISSION

It is the purpose of this plan to:

(a) Provide communications facilities for the immediate transmission of Air Umpire control orders and information as required during every phase of Exercise Swarmer.

(b) Indicate correct routing procedures for Air Umpire traffic.

(c) Outline methods to be utilized in providing unit reports on maneuver activities to the Chief Air Umpire for final evaluation.

2. COMMUNICATIONS FACILITIES

a. Wire will be the primary means of point to point communications for Air Umpire traffic. Circuits will be provided for control orders and umpire information as follows:

(1) Between each Air Base and its Force Headquarters

(2) Between each Force Headquarters and the Chief Air Umpire

(3) Between the Chief Air Umpire and other sections within the Chief Umpire Headquarters.

(4) Between the Liaison Officers of the two Force Headquarters

(5) Between the Air Umpire, U.S. Force Headquarters, and the Tactical Air Force

(6) Between the Air Umpire, U.S. Force Headquarters, and the Tactical Air Control Center

(7) Between the Tactical Air Control Center and each Tactical Air Direction Center

(8) Three (3) circuits between the Chief Air Umpire and the Air Task Force

(9) Between the Chief Air Umpires and the Ground Task Force.

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(10) Necessary switching points will be established at Force Headquarters and JOC-JACC to permit the completion of circuits between Air Umpires and Ground Umpires

(11) Presently existing permanent wire circuits will be utilized between Air Base Umpires and Unit Umpires located on the same installation.

b. The VHF Air-Ground Net will be used by Flying Air Umpires to pass information concerning the Umpire Air Action to other interested umpires, and the transmission of orders. A VHF channel as designated by COI, Maneuver Headquarters, will be used only by Air Umpires. Care must be exercised at all times by Air Umpires flying with Troop Carrier aircraft to preclude excessive use of the aircraft command radio for umpire purposes. Such use of these radios will be made secondary to tactical use. Air Umpires will at all times ascertain that tactical transmission or reception is not contemplated by aircraft crews prior to use of the command radio. The VHF Air-Ground Net will be composed of stations as follows:

(1) Flying Air Umpires

(2) Chief Air Umpires (Mackall Air Base)

(3) Air Umpire, U.S. Force (Mackall Air Base)

(4) Air Umpire, Defense Force (Pope Air Force Base)

(5) Airdrome Umpire (Langley Air Force Base)

(6) Airdrome Umpire (Shaw Air Force Base)

(7) Airdrome Umpire (Congaree Air Base)

(8) Airdrome Umpire (Laxton Air Base)

(9) Airdrome Umpire (Oceana Naval Air Station)

(10) Air Umpire Tactical Air Control Center (Mackall Air Force Base)

(11) Air Umpire Tactical Air Direction Center

(12) Air Umpire Tactical Air Direction Center

(13) Air Umpire Tactical Air Direction Center (Defense)

(14) Ground Umpire (Anti-Aircraft)

(15) Ground Umpire (Anti-Aircraft)

c. HF Radio will be used as the primary means of communications between the Air Umpire, U.S. Force, and the Air Umpire moving between units being resupplied by air within the maneuver area. Further, this channel will serve as a secondary or back-up circuit for those circuit outlined in paragraph 2 a above in the event of saturation and/or failure of wire circuits. HF radio stations will be established as follows:

(1) Chief Air Umpire - - NCS (Mackall Air Base)

(2) Air Umpire, Defense Force (Pope Air Force Base)

(3) Airdrome Umpire (Langley Air Force Base)

(4) Airdrome Umpire (Shaw Air Force Base)

(5) Airdrome Umpire (Maxton Air Base)

(6) Airdrome Umpire (Congaree Air Base)

(7) Airdrome Umpire (Oceana Naval Air Station)

(8) Air Umpire - - Mobile (Fort Bragg Maneuver Area)

d. All radio facilities provided for Air Umpire activities on Mackall Air Base will be installed, and maintained by personnel of the Umpire Group. Those facilities provided other Air Umpire will be installed, operated, and maintained as follows:

(1) On SCR 399 Radio Set will be provided each Air Umpire listed in paragraph 2c above to be installed, operated, and maintained by personnel assigned by the Chief Air Umpire for this purpose.

(2) One SCR 624 Radio Set will be provided each Umpire listed in paragraph 2b above. In the case of those Air Umpires also provided with HF radio facilities, personnel assigned for the installation, operation, and maintenance of SCR 399 Radio Sets will similarly install and maintain VHF ground stations. Those VHF ground stations provided Air Umpires of Tactical Air Control organizations will be installed and operated by personnel of the organization.

3. ROUTING PROCEDURES

a. Channels available for the routing of traffic within the Air Umpire communications net are as indicated on inclusures 1,2,3.

b. Airdrome Umpires will transmit reports to Force Umpires in the manner and priority as listed below:

(1) Wire telephone

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(2) Radio Telephone

(3) Radio Telegraph

(4) Teletype (Command and administrative channels)

(5) VHF radio relay

c. TACC Umpires will make reports to Force Umpires in the same manner as paragraph 3b above.

d. Flying Umpires can make flash reports to any activity included as a part of the VHF airground net as listed on inclosure 2. Reports to be forwarded to the Chief Air Umpire will be transmitted to the station within the nearest proximity to Mackall Air Base, with a request to relay the message to the Chief Air Umpire by wire circuits.

e. Force Umpires will transmit necessary reports to the Chief Air Umpire by telephone.

f. All reports telephoned to an Air Umpire at Umpire Headquarters Mackall Air Base, will be called in to "Air Umpire Report" through the switchboard at Mackall Air Base.

g. A central reporting center will be established by the Chief Air Umpire to receive, transcribe, and deliver all reports received by telephone and radio.

h. The Chief Air Umpire will have available those channels listed in paragraph 3b above for the transmission of control and administrative traffic to subordinate air umpires. In addition, circuits will be available to the Tactical Air Force switchboard insuring access to direct operational circuits to each participating air base for control of tactical organizations.

6. Appendices and Inclosures:

Inclosure 1 - - Wire Diagram

Inclosure 2 - - VHF Radio Net

Inclosure 3 - - HF Radio Net

Appendix 1 - - Communications Operating Instructions

Appendix 2 - - Umpire Check Lists

Appendix 3 - - Radio Frequencies and Call Signs

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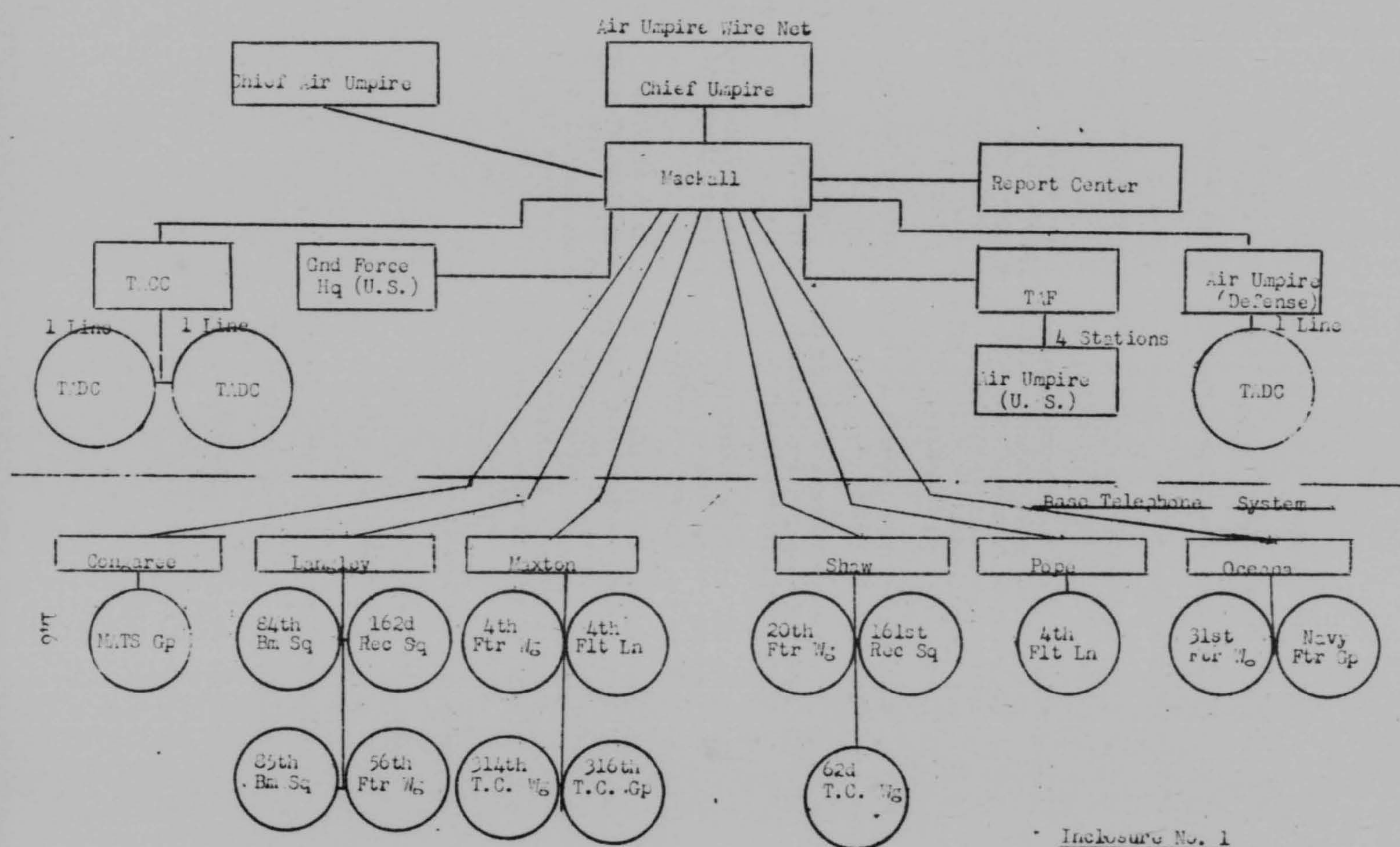
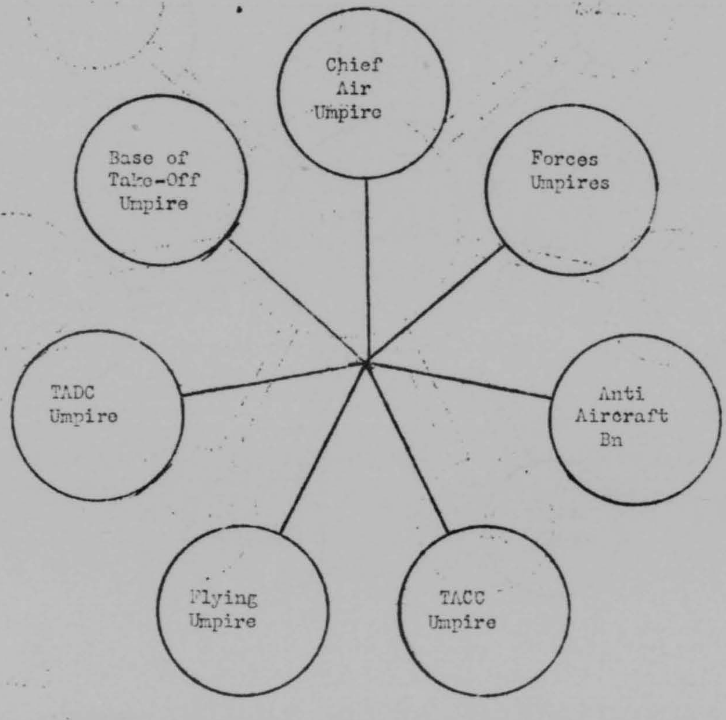


Inclosure No. 1

Inclosure 2
Annex "D"
CAU Oper
Plan 1-50



VHF RADIO NET

Inclosure No. 2

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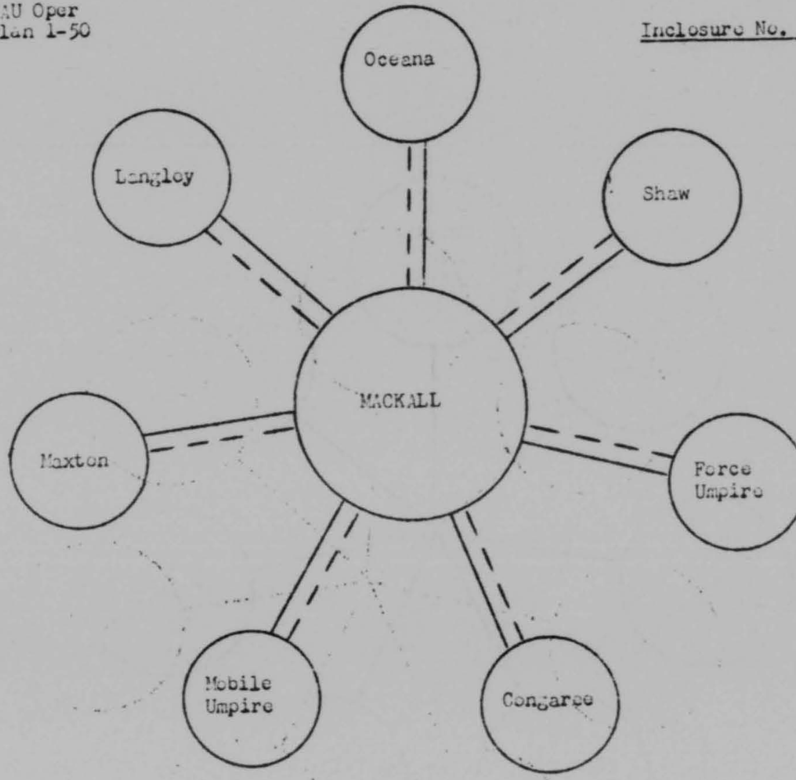
Inclosure 3
Annex "B"
CAU Oper
Plan 1-50

Inclosure No. 3



HF RADIO NET

Legend

Net Control Line__________

Secondary Control Line __ __ __ __

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Appendix 1
Annex B
CAU Oper
Plan 1-50

COMMUNICATIONS OPERATING INSTRUCTIONS

a. GENERAL:

1. This COI will be effective between the dates 1 April - 10 May inclusive.

2. Signal communications within the Air Umpire Group will conform with the instructions listed herein.

3. Any signal matter not covered by these instructions will be reported to the Communications Officer, Air Umpire Group.

4. In the event of communications equipment failure, the Communications Officer, Air Umpire Group, will be notified so that necessary arrangements can be made to effect immediate repairs.

b. AIR UMPIRE COMMUNICATIONS SYSTEMS:

1. Telephone will be the primary means of ground point-to-point communications between Air Umpires.

2. HF Radio will be provided as an overload net.

3. VHF Radio will be used for Air - Ground umpire traffic.

4. Teletype circuits are provided between Maneuver Headquarters at Mackall Air Base and all Air Bases for command and administrative purposes. These teletype circuits may be used by Air Umpires in case of emergency when Air Umpire circuits are not available.

c. TELEPHONE:

1. Wire nets are as indicated on Inclosure 1, Annex B Operations plan 1-50.

2. All telephonic Air Umpire reports at Mackall Air Base will be received by a central reports section, processed, and delivered to the addressee by messenger.

3. Base telephone systems will be used by unit umpires in reporting to Base Umpires.

d. RADIO:

1. HF Radio Nets as indicated on Inclosure 3, Operations Plan 1-50

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2. VHF Radio Nets are as indicated on Appendix 2, Operations Plan 1-50

3. Radio Frequencies and Call Signs are as listed in Appendix 3, Operations Plan 1-50

4. Air Umpire facilities will not use any frequency or call signs listed on Appendix 3, Operations Plan 1-50 without prior approval of the Chief Air Umpire.

5. The highest headquarters operating in the net will act as Net Control Station unless otherwise indicated.

6. All HF Radio stations will be operated from 0800 - 2000 daily unless otherwise directed.

c. RADIO TELEPHONE PROCEDURE:

1. All messages will be clear and concise.

2. Messages will be spoken slowly, in natural phrases, with each word enunciated. Since messages will be copied, time must be allowed for the receiving operator to copy in printed form.

3. All stations will maintain a copy of messages sent and received, including the name of sender and receiver, with the date and time of the originator.

4. When necessary to identify any letter or numeral, the following standard phonetics will be used:

A - ABLE	J - JIG	S - SUGAR
B - BAKER	K - KING	T - TARE
C - CHARLIE	L - LOVE	U - UNCLE
D - DOG	M - MIKE	V - VICTOR
E - EASY	N - NAN	W - WILLIAM
F - FOX	O - OBOE	X - XRAY
G - GEORGE	P - PETER	Y - YOKE
H - HOW	Q - QUEEN	Z - ZEBRA
I - ITEM	R - ROGER	

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1 - WUN	6 - SIX
2 - TOO	7 - SEV - VEN
3 - THUH - REE	8 - ATE
4 - FO - WER	9 - NINER
5 - FI - YIV	0 - ZERO

5. Difficult words will be spelled phonetically and the word will be spoken before and after the spelling, EXAMPLE, "MAXTON - I SPELL, MIKE, ABLE, XRAY, TARE, OBOE, NAN - MAXTON"

6. Numbers will be spoken digit by digit except that exact multiples of hundreds and thousands may be spoken as such. EXAMPLE

39	THUH - REE NINER
14	WUN FO - WER
400	FO - WER HUN - DRED
7568	SEV - VEN FI - YIV SIX - ATE
7000	SEV - VEN THOW - ZAND

7. Dates and time groups will always be spoken by digits.

8. All plain language messages transmitted by radio or wire making reference to simulated enemy or combat forces, such as in combat or amplifying reports will be identified by the use of the word "Umpire" at the beginning and end of the text. This procedure for identifying such traffic is used in order not to alarm units or persons not engaged in Exercise Swarmer.

ELECTRONICS COUNTERMEASURES:

1. No countermeasures will be used against Air Umpire Communications.

2. Any report of jamming of air aids to navigation, Umpire Communications Circuits, or commercial circuits will immediately be reported to the Chief Air Umpire, stating time, frequency, type of jamming, and direction if known.

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SECURITY:

1. Traffic to be routed over Air Umpire Channels will not be enciphered. Traffic of such a nature to warrant enciphering will be enciphered and transmitted by the use of organizational command and administrative facilities.

2. No radio circuit in the Air Umpire net will be authorized as an approved circuit for the transmission of classified information.

3. Careless or excessive use of radio telephone is a serious hazard to transmission security. Since such equipment can be operated by other than trained communication personnel, strict control must be exercised to maintain correct procedure, circuit discipline, and adherence to security precautions.

4. The following malpractices will be avoided:

   a. Misuse and confusion of Call Signs. This may result in the non-delivery of an important message.

   b. Unofficial conversations between operators.

   c. Transmitting in a directed net without permission of the NCS.

   d. Unnecessary transmissions including unnecessary test periods.

   e. Incorrect and unauthorized procedure.

   f. Excessively long calls.

   g. Failure to guard operating frequencies.

5. No authentication will be used on Umpire Channels.

6. Umpire circuits will not be required to observe silence.

7. The Chief Air Umpire will monitor all tactical frequencies utilized during Exercise Swarmer.

TIME: The time zone suffix QUEEN (Q) will be used for all traffic transmitted on Air Umpire Channels.

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Appendix 2
Annex "B"
CAU Oper
Plan 1-50

COMMUNICATIONS CHECK LIST

1. Unit Air Umpires will be provided check lists to provide the necessary guides in furnishing the Chief Air Umpire a comprehensive evaluation of communications and electronics activities as employed during Exercise Swarmer.

2. Check Lists A and B will be used by all unit umpires reporting on units employing communications.

3. Check List C will be used only by Air Umpires reporting on radar activities. Those officers will also be guided by so much of Check Lists A and B as pertains to the type of organization being umpired.

4. Normally all items included on check lists will be used as guides with the final report including only those items that were outstanding or deficient in nature.

5. It is to be borne in mind that reports are intended to give an accurate reflection of the operational effectiveness of the unit being umpired.

CHECK LIST A

Planning and Training Phase

1. Is the communications plan of the next higher headquarters adequate to make provisions for all requirements of the unit being umpired ?
2. Is the Unit Communications Plan adequate to support the mission ?
3. Does the plan provide for an alternate method of communications ?
4. Are all personnel familiar with established SOP or CCI ?
5. Are adequate publications on hand ?
6. Is there any shortage of authorized communications personnel ?
7. Does the T O & E provide sufficient personnel in the necessary classifications ?
8. Is communications briefing of air crews adequate ?
9. Is there a shortage of major items of equipment or supply ? If so, why ?
10. Does the T O & E provide sufficient equipment to perform the mission ?

CHECK LIST B

Operational Phase

1. Were any changes made in the Communications Plan ? Why ?
2. Were any communications problems encountered that were not anticipated ?
3. Were communications facilities adequate ?
4. What communications failures were observed ?
5. To what can these failures be attributed ?
6. Was there any radio interference ? If so, of what nature ?
7. Were adequate physical security measures employed to safeguard classified information ?
8. Was classified communications traffic prepared in accordance with security standards ?
9. Were there any reported violations of cryptographic security ?
10. To what extent can communications be improved ?

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CHECK LIST C

Radar

1. Were radar installations sited such that the maximum capability of the equipment could be exploited?
2. Were interceptions accurately and quickly made?
3. Was jamming encountered?
4. How was jamming or other electrical interference combatted?
5. Was plotting rapid, accurate, and effective?
6. At what range were pips detected on early warning sets?
7. Did operating personnel exhibit adequate qualifications in duty specialties?
8. Was the equipment adequate to perform the mission?

Appendix 3
Annex B
CAU Oper
Plan 1-50

RADIO FREQUENCIES AND CALL SIGNS

(To be published later)

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Annex "C"
CAU Oper
Plan 1-50

AIR UMPIRE SECTION (SWARMER)
Ft Bargg, North Carolina

L O G I S T I C S   I N S T R U C T I O N S

1. The purpose of this annex is to furnish information relative to logistic support for Air Umpires, and guidance in determining and locating data concerning the causes of logistic effect on air operations.

2. Umpires:

a. The 95th Military Government Group, Ft. Bragg, is charged with the responsibility of furnishing billets, mess, transportation, office and school equipment, supplies and Umpires kits for Air Umpires assigned to Ft. Bragg and Camp Mackall. Student Air Umpires will be afforded same facilities as cited above during stay at Ft. Bragg.

b. Umpire personnel assigned to field areas shall be furnished billets, mess transportation, supplies and equipment from organization to which assigned.

3. Concept of data concerning Air Umpire Check-Off list and Score sheet:

a. Supply and Maintenance. In determining the effect of maintenance and supply on the overall mission, it behooves each umpire to secure information from the activity responsible for the performance of that part of the mission affected.

(1) Information leading to logistical plans for tactical and supporting units, and to the availability and condition of required supplies and equipment will be in possession of the Wing Materiel Officer or Organization Commanders.

(2) Information as to adequacy and/or inadequacy of supply and equipment to support organizations can best be obtained from the appropriate accountable officer.

(3) Air Forces and Signal supplies and equipment to support radar, fixed, and mobile communications equipment will be located at each net installation.

(4) To determine technical qualifications of materiel personnel, it is necessary to observe and note their performance of maintenance and supply functions with reference to percentage of aircraft in commission, combat readiness, and mission aborts (Special attention will be given AOCP percentages and its contributing causes.)

(5) Tactical unit facilities are those facilities affording efficient maintenance and arming of aircraft, hangars, maint docks, stands, engine change mounts, jacks, etc., and transportation for loading and ready delivery of supplies and equipment.

(6) Efficient refueling is dependent on proper spotting and spacing of aircraft as well as quantity and quality of the servicing units and operations.

b. Transportation. Comments and recommendations are invited on the adequacy of air and vehicular transportation in relation to its effectiveness in supporting the overall mission.

Annex D
CAU Oper
Plan 1-50

AIR UMPIRE SECTION (SWARMER)
Ft Bragg, Nort Carolina

ADMINISTRATIVE INSTRUCTIONS

ANNEX "D"

1. Strength, Records, and Reports.

a. Morning Reports.

(1) All air umpires and airmen assigned to the Umpire Group will be carried on the morning report of the 95th Mil Govt Det, Exercise Swarmer (Prov), while on duty at Fort Bragg and Camp Mackall.

(2) Air umpires and airmen placed on further TDY with units participating in the maneuver, and who are ordered to return to the Umpire Group at Fort Bragg upon completion of the exercise, will continue to be carried on the morning report of the 95th Mil Govt Det, Exercis Swarmer (Prov), for administrative purposes, and will be picked up on the morning report of the unit to which assigned for quarters and rations only.

(3) Air umpires placed on further TDY to units participating in the maneuver, and who will be directed to report directly to their home station upon completion of the exercis, will be dropped from the morning report of the 95th Mil Govt Det, Exercise Swarmer (Prov) and picked up by the unit to which assigned as umpire.

b. Strength Accountability.

(1) The 95th Mil Gov Det, Exercise Swarmer (Prov), will submit a daily strength report to the Chief Air Umpire indicating the status of all Air Force Personnel assigned to the umpire Group.

(2) Changes in status of air umpires and airmen on duty with units participating in the maneuver will be reported to the Chief Air Umpire by Airdrome umpires.

c. Personnel Records.

(1) Personnel records of airmen will be maintained by the 95th Mil Govt Det, Exercise Swarmer (Prov).

(2) Personnel records of Air Force and Naval Officers will be maintained by the J-1 of Maneuver Headquarters.

d. Effectiveness Reports. Effectiveness Reports will be submitted by the Chief Air Umpire on all officers under his jurisdiction when required by current Air Force directives. Effectiveness Reports are not required for those Air Force officers whose period of TDY is less than sixty (60) days.

e. Disposition of Records. All records on file in the office of the Chief Air Umpire upon completion of the maneuver will be disposed of as directed by the Maneuver Commander.

2. Replacements.

a. Casualties and AWOLs. Air Umpires or airmen casualties or AWOLs serving with units participating in the exercise normally will be replaced by personnel assigned to the office of the Chief Air Umpire.

b. Disposition Upon Return to Duty. Air umpires or airmen returning from hospital or sick-in-quarters to a duty status will report to their immediate superior umpire for instructions. Such personnel normally will be instructed to continue their umpire duties in the exercise.

3. Discipline, Law, and Order.

a. Courts-Martial Jurisdiction. The Commanding General, Fourteenth Air Force, exercises General Courts-Martial jurisdiction over all Air Force personnel assigned to the Umpire Group.

b. Conduct and Dress. All Air Force officers and airmen assigned to duty with the Umpire Group will maintain their dress and appearance, and will conduct themselves in such a manner as to reflect credit upon the United States Air Force.

c. Chain of Command. The normal chain of command for air umpires serving with units participating in the exercise will be from squadron umpire to group umpire, to wing umpire, to airdrome umpire, to Force Umpire, to the Chief Air Umpire.

4. Fatalities.

a. Reports. Air umpire fatalities will be processed through normal channels as required by current directives.

b. Disposition of Effects. Effects of deceased air umpires will be disposed of as provided by current directives.

5. Morale.

a. Postal.

(1) Personnel on duty with the office of the Chief Air Umpire at Fort Bragg or Camp Mackall will have their mail addressed

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with name, grade, service number, and the word "Umpire", followed by "Exercise Swarmer", Fort Bragg, North Carolina.

EXAMPLE: Captain John S. Smith 123456 A
Umpire - Exercise Swarmer
Fort Bragg, North Carolina

(2) Air umpires or airmen serving with units participating in the maneuver will have mail addressed with name, grade, service number, followed by the unit to which attached, and the maneuver base from which the unit is operating.

EXAMPLE: Captain John S. Smith 23456 A
21st Fighter Squadron
Pope AFB, Fort Bragg, North Carolina

b. Finance.

(1) Airmen will be paid on the regular payroll of the 95th Mil Govt Det, Exercise Swarmer (Prov) while at Smoke Bomb Hill, Fort Bragg, and at Camp Mackall. Airmen who are attached to tactical units participating in the exercise will be paid a partial payment prior to their departure, provided the date of departure is such as to justify such payment.

(2) All officers will be responsible for making suitable arrangements with the Post Finance Officer at Fort Bragg, their home station, or, if applicable, the organization which they umpire, regarding their own pay matters.

(3) The 95th Mil Govt Det, Exercise Swarmer (Prov), will prepare travel allowance vouchers for officers and airmen on duty at Fort Bragg, or Camp Mackall.

c. Religious Services.

(1) Religious services for personnel on duty at Fort Bragg will be provided by the Commanding General, Fort Bragg.

(2) Religious services for personnel on duty at Camp Mackall will be provided by the Commanding General, V Corps.

(3) Religious services for personnel serving on duty with tactical units participating in the exercise will be provided by the unit to which they are attached.

d. Decorations and Awards. Current directives regarding recommendations for awards or decorations will apply.

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e. Leaves and Passes:

(1) Passes for air umpires and airmen will not be granted during the actual maneuver period.

(2) Leaves will be authorized only in the case of a bona fide emergency verified by the Red Cross. Such leaves must be approved by the Chief Air Umpire.

6. Administrative Methods:

a. Personnel Requirements:

(1) The Chief Air Umpire will determine the personnel requirements for his staff and for air umpires necessary to umpire the maneuver.

(2) Requisitions for personnel will be submitted to the Maneuver Commander through the Chief Umpire.

b. Assignment of Air Umpires:

(1) The Chief Air Umpire will determine the unit of assignment of all air umpires.

(2) Orders pertaining to the assignment of air umpires and airmen will be issued by the Maneuver Commander upon request from the Chief Air Umpire.

c. Mess:

(1) Messing facilities for officers and airmen serving with tactical units participating in the exercise will be furnished by the unit to which they are assigned.

(2) Messing facilities for officers and airmen on duty with the Chief Air Umpire at Fort Bragg will be furnished by the 95th Mil Govt Group.

(3) Messing facilities for officers and airmen on duty at Camp Mackall will be furnished by the Commanding General, V Corps.

(4) Officers eating in troop messes will pay cash for each meal.

(5) Enlisted men will not be authorized to ration separately.

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d. Quarters:

(1) The 95th Mil Govt Group will provide quarters for all officers and airmen while at Fort Bragg.

(2) Quarters for officers and airmen on duty at Camp Mackall will be provided by the Commanding General, V Corps.

(3) Quarters for officers and airmen serving with tactical units participating in the exercise will be provided by the unit to which attached.

7. Medical:

a. Fort Bragg. The 95th Mil Govt Det, Exercise Swarmer (Prov), will maintain the sick report for all personnel at Fort Bragg. Personnel reporting on sick call will use the facilities of the dispensary in the 4th Signal Bn Area.

b. Camp Mackall. The Commanding General, V Corps, will provide medical facilities for personnel at Camp Mackall.

c. Tactical Units. Medical facilities for air umpires and airmen serving with tactical units participating in the exercise will be provided by the unit to which attached.

8. Miscellaneous:

a. Flying:

(1) Air Force Officers on flying status who are serving as members of the Chief Air Umpires staff will be attached to Pope Air Force Base for flying.

(2) Inadequacy of flying facilities precludes the possibility of furnishing an opportunity to officers attending the Air Umpire School to maintain their flying proficiency.

(3) Air Force Officers on flying status who are serving with tactical units participating in the exercise will be attached to the unit with which serving for flying.

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b. Forms 5: Air umpires on flying status, who report to the Umpire Group for the purpose of attending the Air Umpire School, will retain their Forms 5 in their possession until they report to the tactical unit which they are to umpire, at which time they will turn their Forms 5 over to the Operations Officer of the unit.

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AIR UMPIRE SECTION (SWARMER)
Fort Bragg, North Carolina

ANNEX "E"
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PLAN 1-50

23 February 1950

ANNEX E

Definitions

Airborne - A Term: 1. Applied to personnel, equipment, etc., organically transported by air, such as Airborne Infantry.

2. Used to indicate gear and other equipment not an integral part of the plans, such as Airborne Radar, etc.

3. Applied to an aircraft from the instant it becomes entirely sustained by air until it ceases to be so sustained. A Lighter-Than-Air aircraft is not considered to be airborne when it is attached to the ground, except that moored balloons are airborne whenever sent aloft.

Air Defense - All measures designed to nullify or reduce the effectiveness of the attack of hostile aircraft or guided missiles after they are airborne.

Air Space Reservation - The air space located above an area on the surface of the land or water, designated and set apart by executive order of the President or by a State, Commonwealth, or Territory, over which the flight of aircraft is prohibited or restricted for the purpose of National Defense or for other Governmental purposes.

Air Superiority - That degree of capability (Preponderance in morale and material) of one air force over another which permits the conduct of air operations by the former at a given time and place without prohibitive interference by the opposing Air Force.

Air Support - An air operation designed to create an effect which will assist in the accomplishment of the task assigned the Force as a whole.

Artillery Adjustment - Is the placing of Artillery Fire upon known or suspected enemy installations and/or upon a known point, which may be used as a reference point for shifting fires, using observed or unobserved means after applying Registration corrections to the firing data.

Counter-Intelligence - Is that aspect of intelligence relating to all security control measures, both active and passive, designed to insure the safeguarding of information, personnel, equipment, and installations against the espionage, sabotage, or subversive activities of foreign powers and of disaffected or dissident groups or individuals which constitute a threat to the National Security.

Counter-Measures - That form of Military Science which by the employment of devices and/or techniques, has as its objective the impairment of the operational effectiveness of enemy activity.

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D-Day - The term used to designate the unnamed day on which an initial assault landing or phase of operations is to commence.

Dissemination - The distribution of intelligence and information in such a manner as to insure that it reaches the agencies needing it, in usable form, and in accordance with this urgency.

Echelon - 1. The subdivisions of a headquarters, as forward echelon, rear echelon.

2. Separate levels of Command; as compared to regiment, division is a higher echelon, and battalion is lower echelon.

3. The different fractions of a command in the direction of depth, to each of which a principal combat mission is assigned.

Embarkation - The loading of troops with their supplies and equipment into aircraft.

Escort - 1. To convoy.

2. A combat unit or units assigned to accompany and protect a weaker force.

3. Airplanes assigned to protect other aircraft during a mission.

4. An armed guard that accompanies a convoy, a train, prisoners, etc.

Espionage - The use of secret agents to obtain information concerning a possible or actual enemy or theater of operations, including terrain and weather.

Evacuation - 1. The process of moving casualties from a battle field and subsequently of moving them along the chain of evacuation as necessary.

2. The clearance of personnel, animals, or materiel from a given locality.

Evaluation - The determination of the pertinence, credibility, reliability and accuracy of an item of information.

Fields, Emergency - Landing fields that may be utilized by aircraft which have encountered unforeseen difficulties in flight.

Flight - 1. In Naval and Marine usage a specified group of aircraft usually engaged in a common mission.

2. The basic Tactical Unit in the Air Force, consisting of two or more aircraft.

Force (s) - A body of troops, or aircraft, or combination thereof.

Formation - The arrangement of the elements of a command in any prescribed manner.

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IFF (Identification Friend or Foe) - A system of radio interrogation and reply (if friend). Generally used in connection with radar for identifying an aircraft, ship, or craft.

Intelligence - The product resulting from the collecting, processing and evaluation of information concerning actual and potential situations, conditions and capabilities relating to foreign activities, and to foreign or enemy-held areas.

Interception - 1. The process of flying friendly aircraft to meet a force of hostile aircraft and of engaging the enemy force to hinder or prevent it from carrying out its mission.

2. The process of gaining possession of communications intended for others by copying, recording, or by any other means.

Interdiction - To prevent or hinder, by any means, enemy use of an area or route.

Jamming, Radar - The deliberate radiation of electromagnetic waves to prevent radar from being effective.

Liaison - That contact or intercommunication maintained between parts of an Armed Force to insure mutual understanding and unity of purpose and action. It is often aided by exchange of Officers and/or men in order to keep up an exchange of information.

Logistics - That part of the entire Military activity which deals with production, procurement, storage, transportation, distribution, maintenance and evacuation of personnel, supplies and equipment; with induction, classification assignment, welfare and separation of personnel; and with facilities required for the support of the Military establishment, including construction on and operation thereof. It comprises both planning and implementation.

Organic - Assigned to, and forming an essential part of, a Military Organization. Organic parts of a unit are those listed in its tables of organization for the Army, Air Force, and Marine Corps, and are those assigned to the administrative organization of the operating forces for the Navy.

Organic Air Umpire - An Air Umpire assigned to, and forming an essential part of, the Military Organization upon which he rates and renders umpire reports for an exercise. He is appointed by, and functions as directed by, a member of the Air Umpire Group.

Pathfinders - 1. (Aircraft) Experienced airplane crews who lead a formation to the drop zone, release point, or target.

2. (Airborne) Teams dropped at an objective to establish signal devices for aircraft homing in preparation for an airborne mission.

Psychological Warfare - The employment of any non-lethal means designed to affect the morale and behavior of any group for a specific Military purpose.

Reconnaissance - The directed effort in the field to gather information of the enemy, terrain or resources which is undertaken by an appropriate element of the Armed Forces. Not to be confused with espionage.

Search & Rescue - The use of aircraft, surface craft, submarines, and other special equipment employed for the rescue of personnel in distress on land or at sea.

Security - Measures taken by a command to protect itself from espionage, observation, sabotage, annoyance, or surprise.

Security, Communications - The protection resulting from all measures designed to deny to unauthorized persons information of value which might be derived from communications.

Sortie - One aircraft airborne on a mission against the enemy. Four aircraft would be 4 Sorties, etc.

Strategic Air Warfare - Air combat and supporting operations designed to effect, through the systematic application of force to a selected series of vital targets, the progressive destruction and disintegration of the enemy's war-making capacity to a point at which he no longer retains the ability or the will to wage war.

Strike - Aconcerted air attack on a single objective.

Supply, Air - The delivery by Air of items to drop or landing area.

Support, Close Air - The attack by aircraft of hostile ground targets which are so close to friendly forces as to require detailed integration on each Air Mission with the fire and movement of these forces.

Support, Deep Air - Those supporting air operations that take place in the objective area, but at such range from friendly ground forces as to require no direct coordination between aircraft and front line units other than the establishment of a bomb line, beyond which offensive air operations are unrestricted.

Tactical Air Controller - The Officer in charge of all operations of the tactical control center. He is responsible to the tactical Air Commander for the control of all aircraft and air warning facilities within his area of responsibility.

Tactical Air Control Center (TACC) - The principal air operations installations (land or sea base) from which all aircraft and air warning functions of a tactical air command are controlled. The Tactical Air Control Center is the operational component of the tactical air control group operating at Army or Amphibious Forces level.

Tactical Air Direction Center (TADC) - A subordinate air operations installation (land or sea based) from which all aircraft and air warning operations within a restricted area are directed. The Tactical Air Direction Center is the operational component of a tactical air control group operating at corps level or amphibious group level.

Tactical Air Control Group - (Land-Based) A flexible administrative and Tactical Component of a Tactical Air Force which provides aircraft control and warning functions ashore for offensive and defensive missions within the Tactical Air Force area of responsibility.

Tactical Air Control Party (TACP) - A subordinate operational component of the land-based Tactical Air Control Group designed for the control of aircraft from forward observation posts. The tactical air control party operates at division, regimental, or battalion level.

Theater of Operations - A term used to designate that portion of a theater of war necessary for Military operations, either offensive or defensive, pursuant to an assigned mission and for the administration incident to such Military Operations; theater limits are usually designated by competent authority.

Transport Aircraft - Any airplane designed primarily for the purpose of transportation of material, supplies or passengers.

Troop Carrier Aviation - Air Force Units which are specially organized, equipped, and trained to transport troops and supplies into combat, to re-supply such forces until they are withdrawn or can be supplied by other means, and to evacuate casualties, troops and material.

Troops - A collective term for uniformed Military Personnel (usually not applicable to sailors afloat).

1. (Airborne Troops) - Those troops especially trained to be transported to the combat zone by air and dropped or landed therein.

2. (Combat Troops) - Those units or organizations whose primary mission is destruction of enemy forces and/or installations.

Zone, Drop - A specified area into which airborne troops, equipment or supplies are dropped.

Zone, Landing - A specified zone within an objective area into which gliders or powered aircraft will be landed.

Abbreviations -
1. BCT - Battalion Combat Team
2. COC - Combat Operations Center
3. DCAU - Deputy Chief Air Umpire
4. IFF - Identification Friend or Foe
5. JOC - Joint Operations Center
6. TAC - Tactical Air Controller
7. TACC - Tactical Air Control Center
8. TADC - Tactical Air Direction Center

9. TACG - Tactical Air Control Group

10. TACP - Tactical Air Control Party

11. DZ - Drop Zone

12. LZ - Landing Zone

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HEADQUARTERS
AGGRESSOR FORCE (Exercise SWARMER)
Fort Bragg, N. C.

24 April 1950

SUBJECT: Historical Report

TO: Maneuver Commander
Exercise Swarmer
Camp Mackall, N. C.
ATTN: Historical Section

In compliance with Annex XI, General Plan, Headquarters, Maneuver Commander, Exercise "SWARMER", and Appendix 6 to Annex II - Intelligence - Maneuver Control Order, the Historical Report, Phase I - Planning is hereby submitted.

FOR THE COMMANDING GENERAL:

1 Incl
a/s

J. K. BROCK
Capt., USAF
Secretary

HISTORY

HEADQUARTERS AGGRESSOR FORCE

EXERCISE "SWARMER"

PHASE I - PLANNING

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TABLE OF CONTENTS

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CONCEPT
OF
AGGRESSOR'S ROLE IN EXERCISE "SWARMER"

The general mission of the Aggressor Force in Exercise "SWARMER" was to provide training opposition for the United States Forces in their development and build-up of an airhead completely supplied by air. Due to the preponderance of the United States Ground and Air Forces over that of those representing the Aggressor opposition, the latter force assumed more or less the role of a training aid wherein close control was essential. It was emphaized during the planning phase, that Exercise "SWARMER" was not to be a two-soded maneuver and that the Aggressor Force would furnish opposition subject to the direction and control of the Maneuver Commander through the Chief Umpire.

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KEY PERSONNEL

Aggressor Force Headquarters (CAIDA)

Maj. Gen. Robert M. Lee ---------------- Commanding General

Col. Harry Henry ------------------ Chief of Staff

Col. Henry Viccellio -------------- Deputy Chief of Staff (Air)

Col. William P. Litton ------------ Senior Operations Officer (JOC)

Lt. Col. R.B. Partridge --------------- Deputy Chief of Staff (Ground)

Cmdr. C. E. Dickinson -------------- Deputy Chief of Staff (Navy)

Aggressor Air Force (AGUILITA)

Col. Eugene Sneveley -------------- CO Aggressor Air Force

Col. Earl Dunham ------------------ CO U. S. Air Force Unit

Lt. Cmdr. Plumer ---------------- CO Navy Unit

Aggressor Ground Forces (GALIO)

Col. Dennis Moore ----------------- CO 15th Inf. Regt. (Reinf.)

Lt. Col. John F. Franklin ------------- CO 14th Heavy Tank

Lt. Col. Francis G. Gregory, Jr. ------ CO 70th AAA

Lt. Col. Herbert J. Sparrow ----------- CO 41st Field Art. Bn.

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CHAPTER I

Personnel, Organization and Administration

Aggressor GHQ

Representatives of Aggressor GHQ participated in the preliminary planning conference for Exercise "SWARMER" held at Third Army Headquarters, Fort McPherson, Georgia. Planning was based on joint Army - Air Force directive dated 10 December 1949.

A conference was held at Headquarters Maneuver Commander, Exercise "SWARMER", Fort Bragg, North Carolina 13 - 16 February 1950. Representatives of the Maneuver Commander, Aggressor GHQ, Aggressor Force Commander and the 15th Infantry Regiment were present. The General Plan, Exercise "SWARMER" and the Maneuver Control Order, Exercise "SWARMER" were discussed as the basis for detailed planning. Requirements for Army personnel, equipment, supplies, housing and movements for the Aggressor Forces were determined on this basis and a request for their provision was submitted to the Maneuver Commander. (See Appendix # 1, Troop List of Ground Elements of Aggressor Forces, Exercise "SWARMER"). Representatives of the 15th Infantry Regiment were briefed on converting the Army units to be made available into Aggressor Order of Battle and equipping them for the Exercise.

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Headquarters Aggressor Forces

On 1 March 1950, Major General Robert M. Lee, Commanding General, Tactical Air Command, Langley Air Force Base, Virginia, assumed command of the Aggressor Forces with temporary headquarters at Langley AFB, Virginia.

The Aggressor Force Headquarters was established at Fort Bragg, North Carolina, in the Field Artillery Replacement Training Center Area on 21 March 1950. (See Appendix # 2, General Order No. , and Appendix # 3, Organizational Chart). The Aggressor GHQ joined as part of Aggressor Force and ceased to function as Aggressor GHQ on 21 March 1950.

A conference was held 23 - 24 March 1950 at Headquarters Maneuver Commander, Exercise "SWARMER", Fort Bragg, North Carolina. This conference was concerned with making arragnements for providing Army personnel to perform the functions of units that had not been made available to the Aggressor Forces and checking all other arrangements to date.

All problems pertaining to personnel and administration had been solved satisfactorily except those concerned with the organization of the Headquarters Aggressor Force. The failure to provide a Headquarters Company made it necessary to requisition sufficient individual commissioned and enlisted personnel to handle the administration and housekeeping of the Headquarters. Personnel were provided from different sources

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throughout the Army and Air Force on various dates and were not finally organized until shortly before the tactical phase of the Exercise.

All the Aggressor Force Units were in place at Fort Bragg, North Carolina by 20 April 1950.

15th Infantry Regiment (Reinforced)

Upon receiving notification that the 15th Infantry Regiment was to be the major Army unit of the Aggressor Force to participate in Exercise "SWARMER", action was initiated to secure replacements and obtain logistical support from the 3d Infantry Division and The Infantry Center, Fort Benning, Georgia. Establishment of advance detachments and formation of the Army component in sufficient time to allow participating elements to organise, equip, and train for an Aggressor role became of major importance.

Training in Aggressor tactics was necessary in order to familarize units with Aggressor Tables of Organization. The shortage of Aggressor texts, history, and information pertinent to weapons and equipment, led to direct contactwith Aggressor GHQ at Fort Riley for these materials.

The complexity of the Aggressor mission and organization under Aggressor TO & E's, made it necessary to augment available communications by securing additional signal personnel and equipment. Availability of adequate communications was a

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major factor in insuring Umpire Control and in obtaining maximum effectiveness of the Aggressor Forces as a training aid.

Requisitions were submitted for officer and enlisted personnel to bring units up to authorized strength and to insure maximum effectiveness. Some difficulty was encountered in obtaining release of special duty and detached service personnel from post activities. The 3d Infantry Division supplied the replacements for most of these personnel from units not committed to Exercise "SWARMER".

An overseas levy was received for shipment of 63 enlisted personnel of the 3d Battalion, 15th Infantry, which at the time was below its authorized manning level. Special authority was obtained from the Department of the Army to delay shipment of these personnel until completion of Exercise "SWARMER".

Battery "A" 599th Field Artillery was attached by the Third Army to supplement the strength of the 3d Battalion, 15th Infantry in order to organize an Aggressor Anti-tank Company.

Upon arrival in the maneuver area, units had an effective strength of approximately 80% of TO & E strength.

Considerable difficulty was encountered in obtaining authority to publish competent orders for advance echelon and reconnaissance parties. This condition made it necessary to send personnel to Fort Bragg without competent orders. Strength

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accounting and obtaining rations for the Advance Detachment was most difficult. In order not to delay the planning of the operation, the Regimental Commander authorized the movement of an advanced detachment to Fort Bragg on Movement Orders. Authority to send advanced detachments was secured at a subsequent date from the Third Army.

Detailed planning and coordination was necessary to provide for the administration of rear detachments at home stations. Sufficient trained personnel to handle discharges, retirements, and separations, remained at Fort Benning.

Units forming the Aggressor Force were attached to the 15th Infantry by two different headquarters, specifing different dates. Considerable confusion existed, in that Headquarters SWARMER, attached units for operation while Headquarters V Corps attached the same units for administration.

17th Explosive Ordnance Disposal Squad

On departure from home station, this unit was at T/O strength, and unit TO & E equipment was on hand. The unit traveled by convoy from Fort Knox, Kentucky, to Fort Bragg, North Carolina. Arrangements were made to bivouac in the National Guard Armory's enroute. Unit consisted of one (1) officer, seven (7) enlisted men and three vehicles. No unusual difficulties were encountered by this unit during Phase I.

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Det Signal Sec, 53rd Signal Service Company

Detachment Signal Security, 53rd Signal Service Company, (Army Security Agency) consisting of two (2) officers and twenty five (25) enlisted menwas attached to Headquarters, Aggressor Force, Exercise "SWARMER", by Section V to General Order Number 7, Headquarters Maneuver Commander, Exercise "SWARMER", Fort Bragg, North Carolina, dated 12 March 1950, with effective date of attachment 15 April 1950.

The Detachment was organized from the personnel of Security Monitoring Detachment (UMPIRE) (PROV.), 53rd Signal Service Company, Vint Hill Farm Station, Warrenton, Virginia, and re-designated Detachment Signal Security, 53rd Signal Service Company. The detachment was detached from the 53rd Signal Service Company at Camp MacKall, N. C., on 6 April 1950 and reported to Headquarters Aggressor Force, Fort Bragg, North Carolina on the same date.

ASA Liaison Det

The Army Security Agency Liaison Detachment assigned to Aggressor Forces for Exercise "SWARMER" was activated on or about 1 March 1950 at Arlington Hall Station, Arlington, Virginia, with authorized strength of two (2) officers and nine (9) enlisted men. Arrangements were made for the administration to be handled by home stations of personnel concerned.

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Personnel were attached from other organizations for Exercise "SWARMER" only.

162d Tactical Ron Sqdn (Night Photo)

This unit was faced with a personnel problem when assigned to Aggressor Forces, Exercise "SWARMER". Of sixty four (64) officers authorized only thirty eight (38) were assigned and thirty two (32) were present for duty. Eight of these officers were expected to depart within a short period of time on temporary duty or change of station.

1st Shoran Beacon Unit

The 1st Shoran Beacon Unit was alerted in the latter part of March 1950, to participate in Exercise "SWARMER". The Unit was ordered to be operational by 15 April 1950, however, movement orders were not received until 12 April 1950. The unit departed Langley Air Force Base, Virginia, 13 April by government motor convoy. No troubles were encountered enroute and the unit was operational on 15 April 1950.

CHAPTER II

Intelligence

Aggressor GHQ

During the planning conference 9 - 13 January 1950, the J-2, Headquarters "SWARMER", in collaboration with representatives of Aggressor GHQ prepared the general and special situations of Exercise "SWARMER". The Aggressor situation recited the events prior to and leading up to the arrival of Aggressor Invasion Force in the objective area. The history of Aggressor actions in previous campaigns against the United States, and events leading up to the second Carolina Campaign (SWARMER) were prepared in the form of an Intelligence Summary for release to the United States Forces. This summary covered the Intelligence build-up for the Exercise.

During the planning conferences of 13 - 16 February and 23 - 24 March 1950, an Aggressor GHQ representative collaborated with J-2, Headquarters "SWARMER" in preparation of additional Intelligence Summaries with supporting documents and additional Intelligence releases. No particular Intelligence problems developed.

15th Infantry Regiment (Reinforced)

Advance Detail:

An advance detail consisting of the Regimental Assistant

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S-2 and Battalion S-2's, the I & R Platoon and two draftsmen were sent from Fort Benning, Georgia, to Fort Bragg, N. C. about a month in advance of the main body of the Regiment. The mission of this detail was to keep the Regimental Commander informed of the developments and to prepare for the commitment of the 15th Infantry Regiment (- 1st Bn) in the role of Aggressor in Exercise "SWARMER". Some of the missions accomplished by this detachment indicate the value of this advance preparation:

1. Made route reconnaissance from Fort Benning to Fort Bragg.
2. Requisitioned Maps.
3. Made visual reconnaissance of the terrain.
4. Prepared Tactical Terrain Study. (See Appendix #4, Tactical Study of the Terrain).
5. Converted Recreation Hall into a "War Room" with large wall maps of the Reservation, and organization charts of the United States Ground and Air Forces, of the Aggressor Forces, and of the Umpire Group. This "War Room" was capable of accomodating over two hundred (200) personnel for briefing purposes.
6. Obtained latest texts and other information on Aggressor History, weapons, equipment, tactics and other information from specialists sent by Aggressor GHQ, Fort Riley, Kansas.

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7. Established and maintained liaison with Maneuver Headquarters and Aggressor Headquarters for continuous and current information of interest to the Regimental Commander.
8. Purchased certain items generally not obtainable, i.e. - acetate, grease pencils, plywood and celotex from special funds allocated for Exercise "SWARMER".
9. A rubber terrain model of Fort Bragg Reservation prepared for the Department of the Army and loaned by the 82d Airborne Division added to the interesting collection in the "War Room" and was of considerable aid in early planning for tactical disposition of supporting artillery and anti-aircraft weapons by respective commanders.

Planning at Home Station:

1. Plans were made for converting elements of the Regiment into Aggressor units for the formation of Battle Group "GALLO".
2. Preliminary briefings on Exercise "SWARMER" for the Regimental Commander and Staff and various Infantry School Department Chiefs and Instructors were conducted. Material used was that forwarded from the Advance Echelon at Fort Bragg.

3. The loan of pertinent "vault files" at the Infantry School on such matters as Anti-Airborne Defense, Defense on Extended Frontages and Retrograde Movements was arranged for.
4. Four (4) Aggressor Kits were requisitioned from Tactical Research and New Doctrine, Fort Riley, Kansas. (1 per Bn and Regt'l Hqs)
5. A Regimental CPX using Aggressor designation, symbols, etc., was conducted. COMMENT: (The Regimental CPX revealed lack of familiarity of commanders, staffs and enlisted men in use of Aggressor symbols in the field).

Planning at Fort Bragg:

Upon arrival of main body of 15th Infantry at Fort Bragg, a selection of fifty-three (53) enlisted men was made for Special Duty with the Aggressor POW Detachment. Language qualification was used as the basis for selection.

1. A guide was published for requisitioning of Aggressor uniforms and insignia. (See Appendices # 5 and # 6).
2. Prepared Aggressor Order of Battle Chart, Battle Group "GALLO". (See Appendix # 7).
3. Published Order of Battle on United States 11th Airborne Division and of the 82d Airborne Division.

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4. Prepared briefing on Operation Plans of the United States V Corps and of the 82d Airborne Division to include scheduled drops of RCT's and their objectives, "D" Day to "Day" plus 3.
5. Prepared pass forms for security of Regimental Headquarters and War Room. (See Appendix # 8).

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CHAPTER III

Operations

Aggressor GHQ

During the planning conference of 13 - 16 February 1950, the matter of the troop list of units of the Aggressor Force ground elements was considered and decisions were made as to availability of those units. At that conference, all requested units were reported available except:

a. One (1) Battalion of Infantry.

b. One (1) Headquarters and Headquarters Company, Engineer Combat Group, or equivalent).

c. One (1) Company, Transportation Truck (2½ ton) with twenty four (24) man augmentation team.

d. One (1) Company, Signal Operation.

It was decided that the Headquarters and Headquarters Company, the Truck Company and the Signal Company would not be available, but that efforts would be made to get other personnel and equipment to handle the functions of those units. Plans were made for the movement to Fort Bragg of the Army units to comprise the Aggressor Force. The Commanding Officer, 15th Infantry Regiment was given advice on reorganizing, equipping and training of the Army units in preparation for the Exercise.

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Aggressor Forces

During the conference of 23 - 24 March 1950, it was learned that the Infantry Battalion requested would not be available.

As a result, the requirements for organizing a balanced ground force to play the part of a maneuver enemy could not be entirely met. The Aggressor Force as planned was smaller than is considered desirable for such an Exercise and was not balanced.

15th Infantry Regiment (Reinforced)

The Army component of the Aggressor Force was assigned the mission of providing training opposition to the United States Forces participating in Exercise "SWARMER". The development of this mission began with the planning conferences held at Fort Bragg 13 - 16 February 1950, at which time a broad and general concept was outlined to the Regimental Commander.

A Liaison Group at Fort Bragg, initially representing the 15th Infantry Regimental Commander, was composed of three Officers, - an operations officer, a logistics officer and a communications officer. Subsequent to 11 February 1950, this liaison group was successively augmented on 1, 6, and 21 March by additional increments of staff and operating personnel. The liaison group was responsible for participating in the frequent conferences with Headquarters Maneuver Commander, Headquarters

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Umpire Group, and Headquarters Aggressor Forces, resulting in an approved scenario and a detailed Order of Battle. This group was also responsible for:

a. The channeling of information by physical liaison and electrical means to home bases of participating ground Aggressor units in order to facilitate reorganization into the Aggressor Order of Battle.

b. Preparation and submission of requisitions for the Aggressor Force and the physical acquisition and storage of that material.

c. Preparation of billeting facilities at Fort Bragg and preparation of a broad training program for units participating as Army component of the Aggressor Force in "SWARMER".

d. Selection of training areas at Fort Bragg and extensive reconnaissance of terrain available for Exercise "SWARMER".

e. Preparation of a communication plan and pre-maneuver installation of wire circuits.

f. Rendition of logistical support to Headquarters Aggressor Forces.

Some difficulty was experienced in definitely determining the composition of the Army component of the Aggressor Force. The advisability and desirability of obtaining a third battalion of Infantry were discussed at frequent conferences and were still under discussion during the week prior to the closing of the combat team into Fort Bragg on 7 April 1950. If another battalion had been committed to the Army component of the Aggressor Force at that time logistical support would have been difficult to establish. It appeared that an early and definite decision as to the exact composition of the Army component of the Aggressor Force would have eliminated a great deal of discussion and unnecessary delay in publishing a firm troop list.

Difficulty was experienced in the formation and build-up of the advanced detachment of the Army component of the Aggressor Force at Fort Bragg. Individuals were moved in and maintained at Fort Bragg for periods up to three weeks without competent orders fro such movement. Belated written authority from Headquarters "SWARMER" eventually led to the issuance of a confirming order on the movement of an advanced detachment. Early written authorization for the establishment of advance detachments would obviate an appreciable amount of duplication in administration. The desirability of such advance groups is believed justified by the support rendered, not only to parent organizations, but also to higher echelons arriving with insufficient logistical and administrative support.

It should be noted that during a considerable period of the planning time, the Aggressor GHQ and Aggressor Cadre units were participating in PORTREX. A considerable measure of uncertainity as to the exact compostion (Order of Battle) of the

Army component of the Aggressor Force could have been relieved if this overlap had not existed. Early and continuing competent technical advice is of the utmost value in realizing the full potential of Aggressor as the training aid.

At the first planning conference, the problem of achieving adequate mobility for the Army component of the Aggressor Force was discussed. The establishment of a provisional truck company developed as a logical answer to this problem. The implementation of this plan had not been accomplished on 13 April, some two months subsequent to the initial discussion. An early definite and implemented decision on this question would have facilitated planning.

Artillery units were organized under Aggressor TO & E, and received training in Aggressor tactics to include tactical deployment, unit designations, order of battle, uniforms and equipment.

The planning phase for the tank units consisted primarily in effecting a transition from the TO & E under which the units were organized to Aggressor TO & E. This necessitated forming an Aggressor Tank Regiment from a R/T Heavy Tank Battalion plus one Infantry Regiment Tank Company. Because of the shortage of Officer personnel, the two battalion headquarters were designed to fulfill purely tactical functions, and the Regimental Headquarters was utilized to perform logistical and administrative functions for the battalions. Supply, maintenance,

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reconnaissance, and transportation sections were kept under regimental control. The chief obstacle to the transition was the shortage of communication personnel and equipment.

Command Post Exercises were conducted in defense of drop zones and airfields. Lack of timely information as to the tactical employment of certain elements of the Aggressor Forces precluded advance training that should have been performed. Operational plans should have been drafted sufficiently in advance to allow extensive training, especially where plans require a major change in organization and tactics.

The anti-aircraft battalion was reorganized to provide one Infantry Company in addition to the normal four (4) gun batteries. This reorganization, together with a shortage of sixteen (16) prime movers, had the effect of employing the four firing batteries at 66% of T/O strength and with 20% normal mobility.

The medical support for the 15th Infantry Regiment (Reinforced) for the Aggressor role in Exercise "SWARMER" consisted of the Medical Company, 15th Infantry Regiment (less one platoon), one platoon of the 618th Clearing Company and one platoon of the 559th Ambulance Company. Immediately upon arrival at Fort Bragg, N. C., the collecting platoon became operational and established a central dispensary for the Aggressor ground troops. Aid stations were established by the battalion medical platoons of the 2d and 3d Battalions,

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15th Infantry Regiment, 70th AAA Gun Battalion and the medical section of the 41st Field Artillery Battalion. A central dental clinic was established at the central dispensary and was operated by the Dental Surgeon, 15th Infantry Regiment (Reinforced).

162d Tactical Rcn Sqdn (Night Photo)

A critical shortage existed for qualified Radar Mechanics, Navigation (853); (only two (2) were assigned out of twelve (12) authorized) to perform necessary Shoran maintenance for seventeen (17) aircraft.

The unit was prepared to fly visual and photo reconnaissance, bomber strikes, simulated and/or actual night photography (employing the M56A photo flash bomb over uninhabited areas or D-6 flash which may be employed against any target), intruder, and aerial film drop.

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CHAPTER IV

Logistics

Aggressor GHQ

During the planning conference of 13 - 16 February 1950, arrangements were made for the assembly and housing of the Aggressor Force in the Field Artillery Replacement Training Center, Fort Bragg, N. C. and for provision of necessary facilities, supplies, and maintenance of the base camp. In conjunction with representatives of the 15th Infantry Regiment, requirements for equipment and supplies needed for the Aggressor Force were computed and requisitions were submitted. Arrangements were made with the Umpire Group to provide necessary pyrotechnics for fire markers.

15th Infantry Regiment (Reinforced)

Approximately 60 days prior to the date set for Exercise "SWARMER", logistical plans were initiated. Unit commanders were advised of the necessity of completely equipping their units and directed to inspect in order to determine shortages. Requisitions for all shortages were submitted and filled.

One officer and one enlisted man accompanied the advance detachment to Fort Bragg for the purpose of:

a. Establishing liaison with Fort Bragg post supply agencies and working out with the Maneuver Headquarters, the

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general supply plan required by the formation of the Aggressor Forces.

b. Establishing requirements and drawing in advance the equipment needed to augment normal TO & E equipment, and items of Post, Camp and Station property required for use at Fort Bragg during the training period preceding the Exercise.

The logistical situation in the 70th AAA Gun Battalion developed in an orderly manner. Excellent cooperation received from the Second Army Service units enabled the battalion to move out with practically all the required equipment. The unit utilized the facilities of Camp Lee during the convoy movement.

A full-field inspection was conducted at home stations prior to movement to the Maneuver area. This method provided the commanders with the necessary check to ascertain the actual condition of supplies, equipment, vehicles, and personnel of the participating units. As a result of such inspections, few emergency requisitions were necessary upon arrival in the Maneuver area.

CHAPTER V

Communication

Aggressor GHQ

During the planning conference of 13 - 16 February 1950, requirements of the Aggressor Force for Signal Corps personnel were presented and discussed. Although the signal operation company requested was not available, arrangements were made to provide the Aggressor Force with part of a Signal Construction Company and certain communication teams from a Signal Service Battalion. The Communications Officer, 15th Infantry Regiment was designated as the representative of the Aggressor Force to work out the requirements for frequencies, wire lines, and other communication matters for the Exercise.

15th Infantry Regiment (Reinforced)

Planning for the communications for the Army components of the Aggressor Force was begun on 13 February 1950. To make possible for the Maneuver Commander and the Chief Umpire to control the maneuver, it was necessary to have complete communication control of the Aggressor Forces. It was evident that steps had to be taken to assemble the necessary personnel and equipment to augment that of the participating Aggressor units. A study was made of the communication personnel and

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equipment which were authorized by the TO & E of the 15th Infantry and attached units. Coordinating this with the communication support necessary for the Aggressor Force, alist of augmentation necessary in personnel and equipment was prepared and submitted to the J-5 Section, Headquarters "SWARMER". This list was compared with that of communications troops available for Exercise "SWARMER", and requisitions were prepared and forwarded for the shortage. After a conference with Air Force personnel a list of augmentation personnel and equipment reqired for air-ground communications was also prepared.

A communications operation plan in two parts was prepared. One part was based on authorized personnel and equipment plus augmentation being available and the second authorized personnel and equipment only. These plans were coordinated with J-5, Headquarters "SWARMER."

Difficulty in preparing the communication plan arose in that the tactical employment of the Aggressor Force was not firm at the start of the planning. This made it necessary to formulate a plan that was very flexible. In view of the fact that it would take many man hours to install communication systems this was a definite handicap.

After organizing under the Aggressor TO & E, the chief communication obstacle was the shortage of communication equipment and personnel. To operate all the radio sets which were installed, it was necessary to utilize skeleton crews at each set which was satisfactory only for short periods of time.

24th Signal Service Battalion

During the period 30 March to 13 April 1950, the 24th Signal Service Battalion installed the necessary equipment for the operations of the Aggressor Force Headquarters. One teletype circuit was activated to Langley AFB, and wire circuits for the remaining teletypes were installed and tested pending receipt of equipment for operation.

Four dial trunks were connected to the Fort Bragg switchboard and the line from Fort Bragg switchboard to Langley AFB was extended and patched through to the Senior Operations Officer at JOC. Seven locals were installed in Aggressor Force Headquarters and 10 locals were installed in JOC.

A SCR 399 was set up and tested. A radio schedule was arranged with the Navy at Norfolk but no contact was established. Ten telephones were installed in JOC and the lines laid to remote Control Radio Equipment. Fifteen additional locals were laid.

Cryptographic personnel were assigned to work for the Aggressor Force Crypto Officer. The lack of training in the system which was used was a big obstacle to good operation.

Aggressor Headquarters

The communication section got off to an extremely slow beginning, because of the relatively small amount of information

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available concerning the scope of the maneuver, the units comprising the Aggressor Force, where those units would operate, and details of their operation. Without this information, it was difficult to anticipate the communication systems required. Some of the commercial requirements were requested late because of the addition of extra units and because some committments previously made were withdrawn.

The communications section was comprised of three officers; two to oversee operations at Aggressor Headquarters, at JOC, at TACC, and at all subordinate units, and one officer to supervise the message, and crypto-security centers. This arrangement of personnel worked satisfactorily, but was made too late. For a period of about three weeks, one officer was assigned this duty but was unable to devote more than two days each week because his primary duty kept him at Langley AFB. Some of the last minute requests for facilities might have been eliminated if the section had been up to strength and had more time to secure information for planning.

In this type of maneuver high mobility of Aggressor Force is necessary. Communications depends entirely on communications, it should also be of the best. Must be adequate and flexible. More planning time than was allowed in this maneuver is absolutely necessary.

Communication Center

No crypto officer was provided for Aggressor Force Head-

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quarters until two weeks prior to the Maneuver. Only three crypto technicians were assigned to crypto (2 Pfc's and 1 Pvt). None of the three had valid crypto clearances, but all had undergone a Partial Background Investigation. Only two of the three had operated SIGROD, one had no experience with the M-209, and another had no experience with strip systems. None had been assigned to a regular crypto unit prior to the Maneuver, and not one could change a safe combination. They had not read the crypto instructional books required of all cryptographers prior to operation of the particular systems held by the Aggressor Force.

Due to the lack of tape cutting equipment and patch panels, at Aggressor Force Headquarters all teletype messages had to be sent by hand, and operations reports (which were up to 14 pages in length with four addresses) had to be sent on two different circuits.

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CHAPTER VI

Conclusions and Recommendations

The supporting troops and various attachments to the Aggressor Force should be made known as early as possible to the Aggressor Force Commander so that he may prepare his tactical organization, training schedules, and tentative operation plans for the employment of forces that he can expect to be made available.

An operations plan or scenario should be forthcoming from Maneuver Headquarters at the earliest possible time after the designation of the Aggressor Force to participate in the exercise. Without such a directive, the Aggressor Force cannot publish a plan and subordinate commanders are forced to initiate wha action they deem practicable without knowing the requirements or policy of higher headquarters. The delayed issuance of such a directive can only result in confusion and possible changes to instructions previously announced by commanders of subordinate elements when found to be in conflict with those of higher headquarters published at a later date.

It is the considered opinion of this headquarters, that the Aggressor Force Headquarters should be established early in the planning phase in order to avoid the necessity of subordinate units maintaining liaison with numerous

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higher headquarters during the planning phase. The establishment of the Aggressor Force Headquarters early in the planning phase would eliminate duplication of effort and permit the maximum of efficiency.

It is believed that troops representing the Aggressor Force should close in the Manuever Area at least thirty (30) days but preferably six (6) weeks prior to the beginning of the maneuver. This will permit sufficient time for completion and issue of plans, emplacement of weapons, preparation of positions, and actual training on the ground. If at all possible, Aggressor Force troops should have unrestricted access to the objective area during this period in order to plan and rehearse the tactical play for the exercise.

A fair and equitable portion of SFE funds should be made available to the Aggressor Force Commander at an early date in order that necessary supplies and special equipment considered necessary for the efficient conduct of the maneuver may be purchased.

To insure a clear and definite concept of the Aggressor role in the operation, and early conference between representatives of the Maneuver Commander's Joint Staff, Umpire Group, Aggressor GHQ, and the troop units comprising the Aggressor Force is considered essential. This liaison should be established at an early date and be continuous throughout the planning, training, and tactical phases of the exercise.

This procedure would afford a logical and conclusive concept whereby all participating levels would be in accord as to the excat mission confronting the units representing the Aggressor enemy.

It is the opinion of this headquarters that much benefit would be derived from the assignment of Aggressor GHQ personnel to assist in the training of Aggressor ground units at least forty five (45) days prior to the commencement of the maneuver.

For efficient and complete planning, it is considered essential that authority be granted the commander of the Army component to provide adequate advance detachments under competent orders.

Because of the fact that Exercise "SWARMER" followed so closely after the termination of Operation PORTREX, with overlap of the planning phase of the former and the preparatory tactical and re-deployment phases of the latter, full benefit and assistance could not be reasonably expected from Aggressor GHQ. It would appear that due to the close timing between these two operations, it was necessary to resort to substitution of certain units and delay in furnishing training aids and equipment to the Army units alerted for the Aggressor Force, Exercise "SWARMER".

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HEADQUARTERS
MANEUVER COMMANDER
EXERCISE SWARMER
Fort Bragg, North Carolina

15 February 1950

SUBJECT: Troop list of Ground Element Aggressor Force, Exercise Swarmer.

TO: Maneuver Commander
Exercise Swarmer
Fort Bragg, N. C.

1. References:

a. Department of the Army-Department of the Air Force, Directive of Joint (Army-Air Force) Exercise, FY 1950, dated 10 December 1949.

b. Army Field Forces Publication, Exercise Swarmer, 2 February 1950.

c. D/A Field Manuals, F.M. 30-101, 30-102, 30-103, 30-104, and 105-5.

2. In order to play effectively its part as the maneuver enemy, it is recommended that the Aggressor Force for Exercise Swarmer be provided the following listed numbers and types of units:

a. One (1) regiment of infantry, less one (1) battalion.

b. One (1) battalion of infantry.

c. One (1) battalion of field artillery, light.

d. One (1) company of combat engineers.

e. One (1) battalion of tanks, heavy.

f. One (1) battalion of anti-aircraft artillery.

g. One (1) Headquarters and Headquarters company, engineer group or equivalent.

h. One (1) comapny, signal operations

i. One (1) company, transportation trucks, (2½ ton) with 24 men augmentation team.

j. One (1) company, ordinance medium maintenance.

k. One (1) platoon, medical ambulance company.

l. One (1) platoon, medical clearing company.

m. One (1) platoon, military police company.

ANNEX #1

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n. One (1) platoon, quartermaster service company.

o. One (1) platoon, quartermaster petrol company.

p. One (1) platoon, ordinance ammunition supply company.

q. One (1) counter-intelligence detachment.

r. One (1) MI order of battle Team.

s. One (1) MI photo interpretor team.

t. Four (4) MI Interrogation of prisoners of war teams.

u. Aggressor GHQ units as follows:

(1) Aggressor GHQ

(2) Hq & Hq Det, 47th Engr Com Bn

(3) B Company, 47th Engr Com Bn

(4) Signal Co (Special) 23rd Hq Special Troops

(5) Tactical Information Detachment

v. Of the units listed in sub-paragraph above, B Company, 47th Engr Com Bn is presently at Fort Riley, Kansas. Other units are presently participating in Exercise PORTREX. A Company, 47th Engr Com Bn, similar in composition to B Company, is presently participating in Exercise PORTREX.

3. The above troop list is predicated upon the following assumptions:

a. That the Aggressor Force for Exercise SWARMER will be assembled at Fort Bragg, N. C.

b. That the Aggressor Force during the pre-maneuver training phase will be housed in a base camp in cantonment buildings at Fort Bragg, N. C.

c. That the base camp will be maintained until departure of units from Fort Bragg, N. C.

d. That the ground units of the Aggressor Force will move from the base camp to bivouacs in the maneuver area at such times as required during the pre-maneuver and tactical phases of the Exercise.

e. That because of the small size of the Aggressor Force, and the wide frontages and great depths of terrain over which this force will have to operate, all units must be motorized.

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4. The troop list given above will permit the Commander, Aggressor Force to provide adequate representation of the ground elements of his force, and to support them administratively during the pre-maneuver and tactical phases of the Exercise. The ground elements of the Aggressor Force would be organized so as to represent the units shown on the attached chart (Incl #1).

1 Incl:
Org Chart

/s/ HARRY HENRY
/t/ HARRY HENRY
Colonel, Infantry
Director, Aggressor GHQ

"A CERTIFIED TRUE COPY"

Walter Mazur
WALTER MAZUR
1st Lt., USAF

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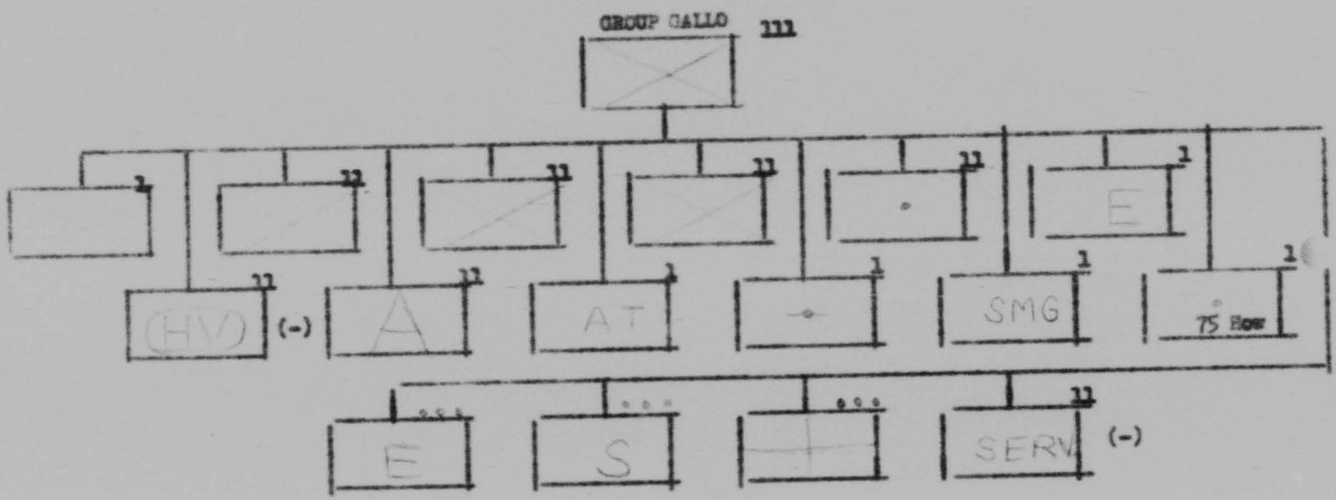
GROUND ELEMENT OF AGGRESSOR FORCE



NOTE: AGGRESSOR GHQ UNITS AND MILITARY INTELLIGENCE UNITS TO BE DISTRIBUTED THROUGHOUT THIS ORGANIZATION AND FORCE HEADQUARTERS PERFORMING FUNCTIONAL DUTIES.

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HEADQUARTERS
AGGRESSOR FORCES (EXERCISE SWARMER)
Langley Air Force Base, Virginia

GENERAL ORDERS
NUMBER 1

1 March 1950

SECTION I

ESTABLISHMENT OF THE AGGRESSOR FORCES (EXERCISE SWARMER)

Pursuant to verbal orders of the Commanding General, Exercise Swarmer, announcement is made of the establishment of the Aggressor Forces (Exercise Swarmer), with headquarters at Langley Air Force Base, Virginia, effective 1 March 1950.

SECTION II

OPENING OF HEADQUARTERS AGGRESSOR FORCES (EXERCISE SWARMER)

Announcement is made of the opening of Headquarters Aggressor Forces (Exercise Swarmer) at Langley Air Force Base, Virginia, 0001 hours, 1 March 1950.

SECTION III

ASSUMPTION OF COMMAND

The undersigned hereby assumes command of the Aggressor Forces (Exercise Swarmer).

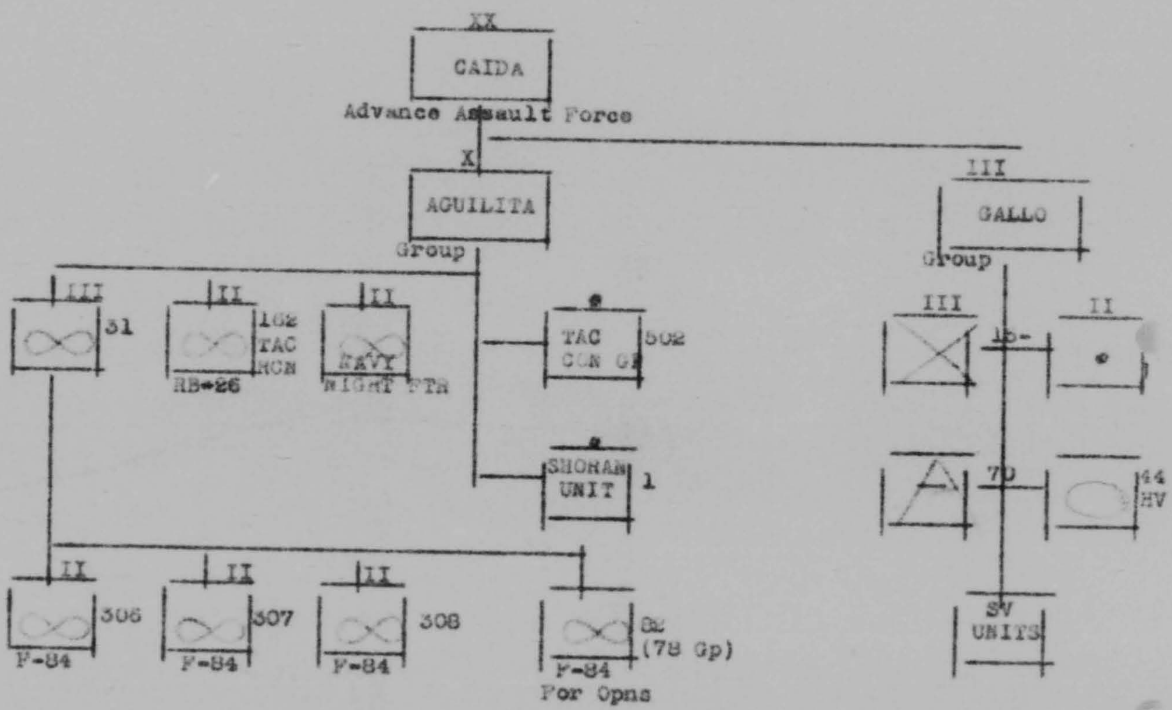
Robert M. Lee

ROBERT M LEE
Major General, USAF
Commanding

DISTRIBUTION:
A

ANNEX #2

ANNEX #3


XX
CAIDA
Advance Assault Force
X
AGUILITA
Group
III
GALLO
Group
III
31
II
162
TAC
RCN
RB-26
II
NAVY
NIGHT FTR
TAC
CON GP
502
SHORAN
UNIT
1
III
15-
II
70
44
HV
II
306
F-84
II
307
F-84
II
308
F-84
82
(78 Gp)
F-84
For Opns
SV
UNITS

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RESTRICTED

TACTICAL STUDY OF THE TERRAIN

a. Fort Bragg.

(1) The reservation at Fort Bragg is generally pear-shaped with the stem pointed to the east, and its center located at 79° 10' 31" W-35° 6' 31" N. The east-west axis is approximately 24.2 miles, and the north-south axis is approximately 11.9 miles at the widest part.

(a) Drainage system. James Creek flows into the Little River and forms the northern boundary of the reservation. A ridge line extends generally through the east-west axis forming a water shed and causing the streams to flow to the north and south. Numerous wet weather streams and small creeks, with an occasional lake, are distributed at regular intervals on the north and south of the water shed.

(b) There is a main ridge line extending generally through the east-west axis with numerous projections to the north and south. There is a second prominent ridge in the southwestern part of the reservation. The highest elevation is approximately 500 feet, and the lowest about 150 feet.

(c) Highways and roads. Three main third class roads extend from Fort Bragg west through the reservation; Manchester Road generally through the center; and Plank Road along the southern boundary. Several dirt roads extend north and south across the reservation forming an excellent network of dry weather roads.

(d) General nature of the Terrain: The terrain is generally rolling and wooded with the heaviest wooded area along the streams. The highest elevation is along the southwest boundary, and center of this area. The lowest elevation is at Pope Field. . .

(2) (a) Avenues of approach and lines of communication: Troops can approach Fort Bragg from any direction. The best route of approach from the west would be along the east-west ridge line.

(b) Obstacles: There are no major obstacles in the area in dry weather. All streams except Little River are fordable. In wet weather motorized units would experience some difficulty in traversing this area due to dirt roads and numerous stream crossings.

(c) Concealment and cover: Cover seems to be generally good-with areas along the streams and creeks providing the best cover.

(d) Observation: Ground observation is good.

(e) Field of fire: Generally 360° of fire exist for all weapons; ideal artillery positions are sometimes difficult to find.

RESTRICTED

ANNEX #4

TACTICAL STUDY OF THE TERRAIN (CONT)

(3) Critical terrain features: The highest elevation is along the extreme southwest boundary. Railroad Ridge, Johnson, Blues, Gaddys, and Coolycoach Mountains are considered critical points in this area.

(4) Tactical effect of the terrain: The terrain in this area is such as to facilitate military operations.

b. Camp Mackall.

(1) Camp Mackall is located 7 miles southwest of Fort Bragg reservation and is separated by a corridor approximately 6 miles wide. The camp itself has no describable shape.

(a) Drainage systems: The area is drained by three main streams; Browning Creek, Swan Creek, and Browning Creek. Numerous other small streams and wet weather streams are distributed throughout the area.

(b) There are two prominent hills and one ridge in the northwest portion of the area. Highest elevation is about 550 feet and the lowest about 250 feet.

(c) Highways and roads: U.S. Highway 1 and the Seaboard Air Line Railway runs through the center of the area from north to south. State Highway 15 and 501 extend through the western portion of the area on a north-south line. Numerous dirt roads and trails form an excellent network of dry weather roads over the entire area.

(d) General nature of the terrain: The terrain is generally rolling and wooded. Most of the area consisted of small farms prior to the time it became a reservation.

(2) (a) Avenues of approach: Troops can approach from any direction. The rolling terrain is adaptable to any troop movements.

(b) Obstacles: There are no major abstacles of note.

(c) Concealment and cover: Cover is generally good. Concealment is thin and spotty in some locations.

(d) Observations: Ground observation is fair.

(e) Fields of fire: Generally 360 degrees of fire exist for all weapons.

(3) Critical terrain features: The critical terrain features are the Sandhills area. The remaining terrain is of such nature as to cause it to be neither critical or vital.

(4) Tactical effect of the terrain: The terrain in this area is such to facilitate military operations.

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Walter Mazur
WALTER MAZUR
1st Lt., USAF

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HEADQUARTERS
15TH INFANTRY (REINF)
Fort Bragg, North Carolina

10 April 1950

MEMORANDUM: Aggressor Uniforms and Insignia

TO: See Distribution

1. The following will serve as a guide for requisitioning the AGGRESSOR uniform and insignia.

2. a. AGGRESSOR UNIFORM:

AGGRESSOR Shirt — AGGRESSOR Helmet or Cap
AGGRESSOR Slacks — AGGRESSOR Field Jacket
Combat Boots

b. Officers will wear the AGGRESSOR overseas cap in lieu of the AGGRESSOR Helmet.

c. The AGGRESSOR uniform will not be worn until ordered by this Headquarters.

3. COMPARATIVE RANKS:

US	AGGRESSOR
Colonel	Colonel
Lt Colonel	Commandant
Major	Major
Captain	Captain
1st Lieutenant	Lieutenant
2nd Lieutenant	Sub-Lieutenant
Warrant Officer	Chief Warrant Officer
Master Sergeant	Sergeant Major - Staff Sergeant
Sergeant First Class	Senior Sergeant
Sergeant	Platoon Sergeant - Section Sergeant
Corporal	Corporal
Private First Class	Senior Private
Private	Private

4. BRANCH AND UNIT INSIGNIA:

UNIT	COLLAR TABS Color	COLLAR TABS Numeral	SLEEVE INSIGNIA COLOR	SLEEVE INSIGNIA NUMERAL
Org Elements 15th Inf	Red (62 Rifle Regt)	62	Red (12 Rifle Div)	12
41st FA Bn (-)	White (134 Arty Regt)	134	Red	12
44th Tk Bn	Yellow (614 Tk Regt)	614	Yellow (IV Mecz Corps)	IV
70th AAA Bn	White (691 AA Regt)	691	Yellow (IV Mec. Corps)	IV
10th Engr Bn	Black (112 Engr Co)	112	Red	12
Service Elements	None		Red	12
AT Co, 112 AT Regt (ATTN: 41st FA Bn)	White	112	Yellow	IV

/s/ V B KOVAC
/t/ V. B. KOVAC
Capt., Inf
S-2

DISTRIBUTION:
1 - CO, 15th Inf (Reinf) & Staff
1 - Regt'l & Bn S-4's
1 - Ea Co, 15th Inf (Reinf)
1 - Ea Atchd Unit, 15th Inf (Reinf)
20 - S-2 File

"A CERTIFIED TRUE COPY"

Walter Mazur
WALTER MAZUR
1st Lt., USAF

ANNEX #5

0459

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SWARMER
CONFIDENTIAL

HQS BATTLE GROUP "GALLO"
Fort Bragg, N. C.

15 April 1950

INTELLIGENCE MEMORANDUM

TO: All Units.

1. SECURITY: a. Yesterday two suspected agents entered the GALLO area, one posing as an inspector of Mess-Halls and the other as a civilian photographer. The "Inspec tor" was apprehended, delivered to GALLO Intelligence Officer and processed, while the other was merely told to get a clearance from Headquarters and promptly escaped. It is repeated that suspects be taken to local Intelligence Officer for processing or clearance.

b. A pass system for personnel authorized to enter this Headquarters is in effect. Subordinate units will adopt a local pass system of their own, to be limited to entry of CP's and vital installations.

2. INSIGNIA: a. Some slight changes have been made by Aggressor Headquarters to the uniform insignia published in Memorandum dated 10 April. The correeted insignia is as follows:

Unit	Collar Tabs Color	Collar Tabs Numeral	Sleeve Insignia Color	Sleeve Insignia Numeral
Organic Els 62 Rifle Regt	Red	62	Red	12
134 Arty Regt	White	134	Red	12
614 Tank Regt	Yellow	614	Red	NONE
691 AA Regt	White	691	Red	NONE
112 Engr Co	Black	112	Red	12
Service Elements - 112 Sv Bn	NONE		Red	12
AT Co, 112 AT Regt	White	112	Red	12

b. Collar tabs and sleeve insignia will not be worn until 240001 April 1950, when the situation becomes TACTICAL.

3. AGGRESSOR WEAPONS: Weapon characteristics and performance listed on page 146, FM 30-102 will be credited by Umpires. Unit commanders should be aware of the support of such weapons as 120-mm artillery pieces, 80-mm AA guns in ground support, and 105-mm AT guns. The tank gun (US 76-mm) will be credited as AGG 90-mm tank gun. Performace of the 80-mm AA gun, NOT listed in the above FM, is as follows:

Maximum ceiling	40,000 feet
Maximum horizontal range	19,000 yards
Muzzle velocity	2,950 ft/sec

4. AGGRESSOR NAMES: a. In order to get both officer and enlisted personnel familiar with the Aggressor names of commander and staff members, assigned names will become effective upon movement to the field 19 April 1950. They will be used throughout the tactical situation.

b. A limited distribution of the Aggressor O/B including both U.S. and Aggressor names will be published soon.

c. An Aggressor identification card overstamped with "Exercise SWARMER" will be issued to each officer. The Aggressor name shouls be entered in print, and "authenticated" by the officer's own signature.

BY ORDER OF COLONEL YABAN:

/s/ LOUIS GOMEZ
/t/ LOUIS GOMEZ
Major, Infantry
Adjutant

DISTRIBUTION:

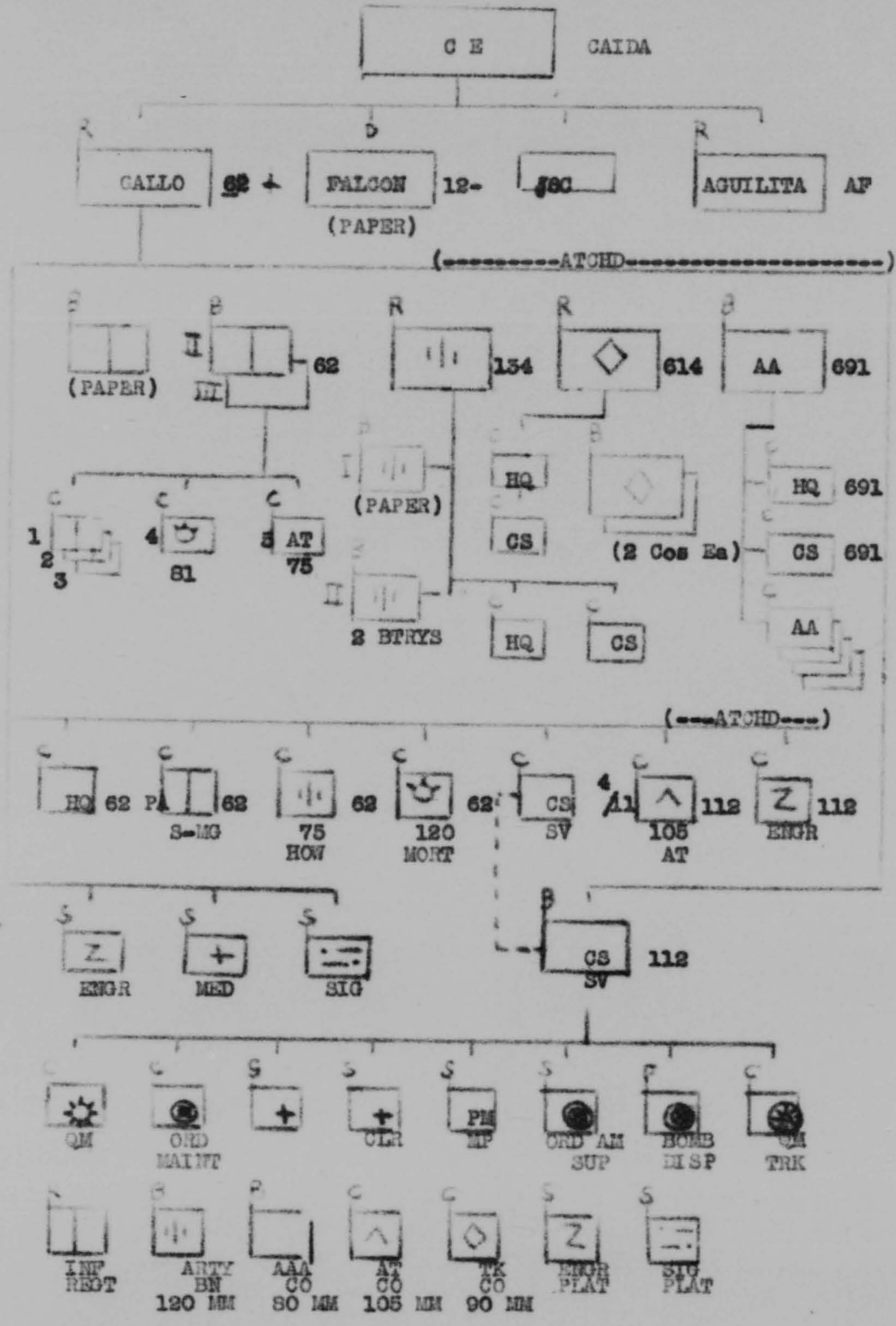
CO's & STAFFS
1 ea Co & Atchd Unit

SWARMER
CONFIDENTIAL

" A CERTIFIED TRUE COPY "
Walter Mazur
1st Lt USAF

0460

"SWARMER" SECRET



"SWARMER" SECRET

DISTR: 1 Ea Officer
Gp GALLO

S-2 SEC 15TH INFANTRY

ANNEX #7

0461

"EXERCISE SWARMER"
AGGRESSOR IDENTIFICATION OF

________________________ BEARER
PASS TO ENTER THIS HEADQUARTERS

T D Eckols 101
ADJUTANT

SAMPLE

ANNEX #8

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HISTORY

HEADQUARTERS AGGRESSOR FORCE

EXERCISE "SWARMER"

PHASE II - TRAINING

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TABLE OF CONTENTS

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INTRODUCTION

Upon arrival in the Maneuver Area, Units assigned to the Aggressor Force became the training responsibility of the Aggressor Force Commander. Under the direction of Headquarters Aggressor Force, the unit commanders completed the necessary arrangements for the administration and tactical preparation of their units for participation in the Exercise.

Action was taken to accomplish: Orientation briefings and demonstrations on Aggressor techniques and equipment; reorganization and equipping of United States Units under the Aggressor Order of Battle; and instruction in Aggressor history; organization and uniforms, and the Operations Plan, Aggressor Force.

Action was taken to accomplish: The reconnaissance of the objective area to locate the key terrain features and routes, and to determine the time and space factors; Instruction of specialists for operation of special Aggressor equipment and employment of special Aggressor techniques; preparation of detailed tactical plans, and the walk through and rehearsals of these plans.

Action was taken to accomplish: Instruction of Army units in function of joint Army - Air Force control activities such as JOC, TACC, TADC, TACP, and SHORAN; instruction of air units in the tactical operations to be conducted by ground units, and rehearsals of joint Army - Air Force operation.

Action was taken to accomplish: Preparation and occupation of service area installations; preparation and occupation of defensive positions, weapons emplacement, CP's and other forward area installations;

distribution of supplies; and implementation of the pre-maneuver phase of agent play, psychological warfare play, and tactical radio net play.

Detailed discussion of the above matters are covered in the following chapters.

CHAPTER I

Training

The Aggressor GHQ and Cadre Units conducted, during the pre- maneuver training phase, two hour orientation briefings and demonstrations for interested personnel of the Umpire Group, 15th Infantry Regiment (Reinforced), and Tactical Air Command and Air Force and Naval Air Units of the Aggressor Force. These presentations took place 31 March, 7 - 12 April, and 17 April 1950 respectively and included discussions of the "Why of Aggressor", and "What Aggressor Does and How it is Done"; and demonstrations of "What Aggressor Uses and How it is Used".

A group of specially selected personnel of the 503rd CIC detachment under the CIC Officer of this Headquarters, were given training to prepare them to play the part of Aggressor Agents against the U.S. Forces. Each agent was furnished identification and other Aggressor documents and drilled in a cover story. They reconnoitered sensitive areas of selected installations of the U.S. Force and made plans for the clandestine penetration of such areas in various disguises. Each agent was given the overall missions of testing the security of the U.S. Forces and securing information of intelligence value to the Aggressor Force. Some agents were given the additional mission of distributing subversive propaganda, and others to execute sabotage. During the period 10-20 April restricted agent play was conducted against the U.S. Forces to test their security, secure information and distribute propaganda (See Annexes 1 thru 4). Beginning with 21 April, agent play was unrestricted, so sabotage missions were included.

The Detachment of the 525th MI Serv Platoon, under the IPW Officer of this Headquarters, prepared cover stories and documents for use of Aggressor prisoners, casualties, and deserters. Based on the tactical plan of the Aggressor Force, a schedule for the release of prisoners and documents was prepared. During the period 10-26 April, a group of fifty enlisted men furnished by the 15th Infantry Regiment (Reinf) were given training to prepare them to play the part of the Aggressor prisoners, casualties and deserters to be released to the U. S. Forces during the tactical phase of the Exercise.

The Tactical Information Detachment prepared psychological warfare documents for distribution to the U. S. Forces during the training and tactical phases of the Exercise. Reconnaissance was made of the objective area and plans were made for the projection of loudspeaker propaganda broadcasts during the tactical phase.

The Signal Company (Special) Headquarters, 23rd Special Troops prepared and mounted sonic equipment, and trained eighteen enlisted men of the 15th Infantry Regiment (Reinf) to operate large and small sonic units during the tactical phase of the Exercise. Reconnaissance was conducted in the objective area, and plans were made for the employment of the large sonic units with the fire marking teams, and the small sonic units with the infantry battalions. Rehearsals were conducted with the organizations to which attached.

Personnel of "A" Company, 47th Engineer Camouflage Battalion trained selected personnel of the 15th Infantry Regiment (Reinf) in the operation and maintenance of artillery flash simulators and assisted in the preparation of dummy positions and emplacement of flash simulators and pneumatic targets for deception purposes.

The Artillery Staff Officer of the Aggressor Headquarters directed and supervised the field training of Fire Marking Teams assigned to the Aggressor Force, and advised the Commander, Group CAILO Artillery in the employment of Aggressor techniques for indirect fire weapons. The G-2 and G-3 Staff Officers engaged in joint training exercises in the Joint Operations Center in the preparation for performing duties with the JOC during the tactical phase of the Exercise.

A Detachment of the ASA established and operated a simulated Aggressor tactical radio net, over which was transmitted, in a special code, certain messages that included information of intelligence value to the United States Forces. A specially equipped ASA team reconnoitered the area to be used by the United States Forces to locate sensitive points for using wire intercept equipment. An ASA radio monitoring team monitored radio traffic of the United States Forces to detect violations of transmission procedures and infractions of communications security.

The Military Government team of the Aggressor Force prepared documents for use in the Exercise. (See Annexes 4 thru 17)

The training phase for the 15th Infantry Regiment and all units attached to it began upon arrival in the Maneuver Area. Essentially, the training resolved itself into two main phases; the reorganization into Aggressor Components, and the rehearsals of the appropriate

Aggressor mission. Administrative personnel were required to attend Aggressor orientations and demonstrations in order to become familiar with Aggressor organization, weapons and tactics.

Special emphasis was placed on prisoner of war training, (including interrogation) order of battle and guerilla tactics. Units were instructed in security of military information and counter intelligence measures. Numerous briefings and orientations were held for Umpires and Aggressor Force Commander based upon information received concerning plans of the opposing forces. Timely information as to plans of the United States Forces assisted in formulating the Aggressor Operational plan with a view toward affording U. S. Forces a maximum of opposition with a minimum of personnel.

Training was also conducted on tactics, communications and camouflage; reconnaissance of maneuver area; tactical employment and normal missions of a tank unit, AA gun unit and combat engineer unit; daylight and blackout convoy movements; and organization of defense positions and night displacement.

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RECOMMENDATIONS

Units designated to participate in the Exercise as part of the Aggressor Force be assembled in or near the objective area four to six weeks prior to the start of the tactical phase.

oooooo

Orientation briefings and demonstrations by the Aggressor GHQ and Cadre Units be presented to all personnel of the Aggressor Force shortly after its assembly, and before other training starts.

oooooo

Personnel to be trained as specialists in the operation of special Aggressor equipment, or for employment of special Aggressor techniques, be made available for instruction shortly after the Aggressor Force is assembled.

oooooo

All special items of equipment and supplies required to equip the Aggressor Force be available at the time and place the Aggressor Force is assembled.

oooooo

Until they leave their home stations, units of the Aggressor Force continue training under current programs, so modified as to include subjects considered essential in preparing for the type of tactical operations to be conducted in the Exercise.

oooooo

When the Aggressor Force is assembled four weeks or more prior to the start of the tactical phase, training in most Aggressor subjects be conducted after the arrival of the Aggressor GHQ and Cadre Units with their instructor personnel and special equipment.

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CHAPTER II

Operations

Personnel continued to present a problem to the 162nd Tactical Reconnaissance Squadron, Night Photographic. The unit had five and one-half ($5\frac{1}{2}$) complete crews available for operational work during the training phase. In order to meet the flying committments, crews had been reduced by one navigator, making eleven (11) skeleton crews available for operations.

During the training phase, the Unit flew photo reconnaissance, shoran pinpoint, and aerial film delivery missions. Equipment difficulties plus the weather conditions precluded complete success on the Shoran missions which were assigned to the unit. Continuous maintenance on radar equipment is necessary to eliminate repetitive malfunctions.

The 1st Shoran Beacon Unit computed the five (5) Shoran missions flown by the 162nd Reconnaissance Squadron. Although one (1) of the missions was reported completed, it was later reported as unsuccessful because of camera malfunction. One mission was entirely aborted, and the other missions were unsuccessful because of insufficient training of the Shoran Navigators. All failures were found to be in the airborne sets and were caused by the Navigators not having sufficient training in this special set.

As experience has shown, in order to keep abreast and ahead of expectations from Higher Headquarters, sufficient targets were computed and forwarded to the Joint Operations Center in order that there would be no delay in the time of requesting and receiving a missions computation. The targets consisted of Aberdeen Airport, Bennetsville Water Tower, Dillon Water Tower, City of Southern Pines, Ranger Station and Water Dam at Fort Bragg, Maxton and Marshalling Yard at Maxton.

Aggressor Force Joint Operations Center and Tactical Air Control Center building was set up by the 502d Tactical Control Group. JOC started 24 hour day operations on 16 April 1950. Since no personnel experienced in JOC operations were assigned to the Aggressor JOC, arrangements were made with TAF, whereby representatives of the Headquarters presented briefings on administrative details and record keeping pertaining to JOC operations.

This training period was sufficient to train personnel, coordinate with the subordinate units, and work out details of operation. Orientation missions were laid on for 17, 18 and 19 April and training missions were scheduled 20 through 23 April. For breakdown of missions and sorties flown during this period and their results, Table No. 1.

Communication was the most unsatisfactory part of the operations of the JOC. Poor planning and poor results were evident.

In compliance with verbal instructions from Aggressor Force Headquarters, the 31st Fighter Group (Fighter-Bomber) participated in flying training from 16 thru 23 April. During this period, Squadrons of the 31st Fighter Group participated in a scheduled two - one and one half hour sorties per operational aircraft per day. Missions flown included normal unit formation, tactics, and area familiarization flights. These

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were made from Langley AFB to the Fort Bragg, MacKall and Maxton-Laurinburg areas. Inaddition, training flights were conducted in conjunction with the Tactical Air Control Center, the Tactical Air Direction Center and a Forward Air Control Party.

The training phase for the Naval Unit of the Aggressor Force participating in the Exercise commenced on 15 April 1950. The Unit, composed of eight (8) F4U5N, four (4) AD-2Q, and one (1) P2V type aircraft, progressed smoothly through the training period which consisted of night area familiarization, night tactical work such as intercept missions, intruder missions, and night strikes.

None other than normal problems incident to operations away from home station were encountered. Some difficulties were caused by late receipt of directives and operational orders.

TABLE NO. 1

TYPE	NUMBER SCHEDULED	NUMBER RUN	RESULTS
Photo Reconnaissance	35	32	25 Successful
Night Intruder	10	5	3 Successful
Bombing Day and Night	1	0	0 Successful
Strafing	0	0	0 Successful
Pinpoint Photo	7	5	5 Successful
Shoran Photo	5	5	0 Successful
Jamming	1	1	1 Successful
Fighter Sweep	15	12	11 Successful
Fighter Strike	3	0	0 Successful
Standby Alert	10	8	5 Successful
Intercept	5	2	2 Successful
Familiarization Flights	10	10	10 Successful
Close Support	2	2	2 Successful

Period covered from 17 April thru 23 April 1950

Sortles Scheduled 417
Sorties Completed 318

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CHAPTER III

Logistics

The 15th Infantry Regiment furnished logisitical support to all attached army units, and established POL distribution points and field supply dumps. The primary difficulty throughout this entire period was the requirement for processing and unnecessary large number of individual requisitions and resulting issues. This factor over-burdened clerical facilities of both regimental and post supply agencies, causing bottlenecks which in turn wasted manpower and transport. Had innumerable small requests been planned ahead and consolidated by units, a considerable ease of operation would have resulted.

A number of Aggressor Force units arrived in the Maneuver Area in short supply; In some cases entirely without certain expendable supplies (TA 10-100) that should have been brought from home stations. Some individuals, particularly those who arrived and joined their units in the Maneuver Area, where without proper clothing and equipment.

These deficiencies resulted in numerous requisitions that would have not been necessary had instructions published by SWARMER Headquarters been followed in this matter.

Aggressor uniforms and insignia were difficult to get in proper quantities. An excess of extremely small sizes was available but properly fitting Aggressor uniforms were not available.

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CHAPTER IV

Communications

Actual training of a limited amount was accomplished by the communication units that were operational during this period, with the exception of the 9466th TSU, and an HF Radio Unit which were committed to the Aggressor Force on the 19th April and were not operational during the training phase.

The time allocated to the training phase was used more for planning purposes than for training because of the late period that the Communications section was initiated in this Exercise.

On 22 April 1950, another direct telephone trunk line was installed from the Maneuver Headquarters to Aggressor Force Headquarters to alleviate the exceptionally heavy amount of traffic between these two points.

Army Security Agency and other crypto planners attempted no overall plan for providing adequate crypto facilities for all participating units in the Maneuver. What was planned, such as composite holders charts, was incomplete and artificial. The crypto material was simply "dumped" on the Aggressor Headquarters custodian to be disposed of as he saw fit. In two weeks time he was expected to set up his own crypto facility to handle traffic for Aggressor Headquarters, JOC and TACC Aggressor, and for the various Air Umpires. In addition, he had to determine as best he could which outfits were Aggressor units, who were the properly cleared custodians at each unit, what systems should be utilized at each unit, and the required indoctrination of personnel at each unit.

Maneuver and Umpire manuals proved not merely ineffectual on classification problems, they were misleading, confusing, and were not conducive to security in general. As a consequence, much crypto material was passed out to custodians of questionable reliability. As far as can be determined, encrypted Aggressor traffic passed only between Aggressor Headquarters and MANCOM. Not once did a crypto man at Langley or Norfolk encrypt its so-called Swarmer Secret traffic. The Manuals did not mention Confidential classification or low precedences; consequently, all units marked their traffic "Secret" and then sent it Priority or Operational Priority in clear text. They also made free use of the telephone for bogus Secret traffic, and often left it unattended for free observation by unauthorized personnel.

Only after the Training Phase began was the Communications Center informed that tactical maneuver traffic could not use world-wide nets. Nearly every message went to both Langley and Norfolk, but both were not on a common net. Consequently, messages had to be sent over two M-15 machines simultaneously. Ops reports up to twelve and fourteen pages, classified Secret and showing OP precedences, could not be partically transmitted by two crypto clerks using the M-209 Converter or other low grade systems which were authorized for use. Efforts to secure a Class "A" system from Langley AFB and Norfolk ended in failure. The only reply from A.S.A. was to "break the messages into two parts and put and operator on each part".

Since practical common systems were not held by major Aggressor units, very little training was possible. Two clerks at Aggressor Headquarters got their first training in accounting for crypto material, in answering violation reports, and in use of systems not known to them previously. United States Force intercept teams obviously had fruitless hours of waiting for traffic that did not appear.

The establishment of a communication plan to fit the operational plan of the 15th Infantry Regiment (Reinforced) presented some difficulty because of the shortage of personnel and equipment. The communications system was considered excellent in its overall plan and proved the value of prior planning and intensive training. The actual radio net organization was established well in advance, and personnel were given training at their actual locations in the maneuver area.

RECOMMENDATIONS

Units participating in the Exercise should be determined at the earliest possible date. This list should be turned over to the J - 5 Section of the Maneuver Headquarters. J - 5 Section should then provide for one Class "A" and one reserve crypto system at each base or post participating. J - 5 should also indoctrinate and assign such personnel as will be required at each crypto unit to perform crypto duties for all parties of either side requiring crypto duty.

******

Smaller units should have Class "B" systems - never more than one - and an enlisted man operator for each unit would be sufficient. These enlisted men would be directly under J - 5, and attached for the crypto duty, then a Holders Chart would be unnecessary, and duplicate sets of Maneuver systems would be unnecessary. Furthermore, classified traffic would get the properclassification rather than haphazard and insecure treatment.

******

Double classification of Maneuver traffic should be eliminated. If theclassification of Secret is necessary at the time of transmittal, the message can easily be downgraded to Restricted or unclassified upon completion of the Exercise in accordance with existing directives. Military personnel safeguard Secret matter; they give Maneuver Secret an unclassified treatment. Manuals should not require every Maneuver document to be secret nor of Operational precedence. Current directives

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also cover this subject.

******

Proper clearance for custodianship of crypto material should be a J-5 function and all crypto personnel sent out by J-5 would assume such crypto custody as required for his particular needs. Then all systems would be used as necessary at all stations by experts.

Messages which must be telephoned should never be classified. Experienced crypto personnel would not thus comprise crypto security, and should be a party in overall communications planning. Classified traffic not in use should be stored securely by the Secretary of the Crypto Officer.

******

Subordinate Aggressor units should be put on a common teletype net with Aggressor Headquarters, and tape transmission should be provided at least for the Headquarters unit.

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STAYFAST

13-F

419.7174-5
Apr-May 1950

SWARMER

SWARMER AFTER OPER

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13B

[redacted]

CRITIQUE

EXERCISE SWARMER

JOINT ARMY-AIR FORCE MANEUVER

FORT BRAGG - CAMP MACKALL

5 MAY 1950

[redacted]

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HEADQUARTERS
MANEUVER COMMANDER
EXERCISE SWARMER
Fort Bragg - Camp Mackall
North Carolina

CRITIQUE

At 0800 hours on 5 May 1950, the commanding generals and high ranking officers connected with the maneuver, Exercise Swarmer, gathered together in the building occupied by Umpire Headquarters at Camp Mackall for a summary of events. Lt Gen Norstad opened the session by welcoming the officers to this second part of the maneuver, and giving the order of events scheduled. The commanding general of each force was given an opportunity to speak and present the high points of the maneuver from his particular viewpoint. Recommendations were made as to how future maneuvers of this type might be improved. For the purpose of further reference and study, the remarks of each speaker are hereby incorporated into the final maneuver report.

Maneuver Commander
Lt Gen Lauris Norstad, USAF

Umpire Group
Brig Gen Gerald J. Higgins, USA

Aggressor Forces
Maj Gen Robert M. Lee, USAF

Task Force Swarmer
Lt Gen John R. Hodge, USA

V Corps
Maj Gen P. W. Clarkson, USA

Air Task Force Swarmer
Brig Gen W. R. Wolfinbarger, USAF

Carolina Base Section
Brig Gen Paul F. Yount, USA

COMMENTS BY BRIG GEN GERALD J. HIGGINS, CHIEF UMPIRE

It is my plan, in the limited time available, to present a chronological report on the maneuver, beginning with preliminary air operations and ending with the coordinated ground assault on Fayetteville airport. I will intersperse certain comments and observations on particular actions where appropriate, and furnish certain statistical data where necessary. My summary will reflect, in general, the consensus of opinion of senior air, airborne and ground umpires who have closely followed the exercise from inception to conclusion. It is hoped that commanders concerned will accept critical remarks in the same vein in which they are offered--an honest desire on the part of the Umpire Group to assist in our country's preparedness by correcting weaknesses and mistakes as indicated by performances of individuals and units during the actual maneuver. Many points are highly controversial, of course, and arguments may well be in order. However, in most cases such arguments boil down to whether or not the enemy has certain capabilities, and we in the Umpire Group feel that our mission will be accomplished if we can bring such controversies to the attention of those charged with the planning and execution of future operations to the end that adequate provision will be made to cope with such enemy capabilities.

I am assuming that all of you are familiar with the background of this exercise, and therefore I will not spend time on preliminaries and events leading up to the launching of Airborne Operations Swarmer. In order to save as much time as possible, I have asked Colonel Leahy to assist me by indicating on the maps the play of the exercise in chronological order.

On April 15th United States Air Forces began flying photo reconnaissance missions; an average of twelve missions per day were flown for the next nine days.

D-day - 4:

The war proper began on 24 April 1950. Aggressor committed the overt act by raiding the U.S. Forces field at Laurinburg-Maxton at 0001, 24 April 1950, and continued throughout the day for a total of twenty two missions; U.S. Air Forces flew a total of sixty missions. The number of sorties, of course, was much higher. The air umpire staff is of the opinion that on this date the United States Air Forces violated accepted tactical doctrine, in that they applied too much of their strength against Phase II targets, i.e., ground objectives, before a high degree of air superiority had been attained. Umpire records indicate that on this date 57% of United States Air Forces effort was devoted to Phase I missions, and 43% to Phase II missions.

D-day - 3:

On the following day, April 25, the United States Air Forces quickly reversed this policy and applied 81% of their Air Force to missions designed to gain air superiority. The umpire figures clearly indicate

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that the considerable number of losses suffered by United States Air Forces could have been reduced by decisively employing aircraft in gaining air superiority before applying air strength to battle field objectives.

On this date, April 25th, United States Air Forces flew a total of 41 missions, and the Aggressor flew 9. On the evening of April 25th the United States Air Forces received actual reinforcement of one fighter group; the group became effective April 26th. The United States Air Forces, due to this reinforcement, and the numerous Aggressor losses, created a situation of air superiority to such a degree that the moving in of airborne troops was considered a good calculated risk. The Aggressor, however, had sufficient remaining strength to inflict some damage to U.S. Air Forces aircraft and installations. It was the view of the Air umpire staff that U.S. Air Forces had, at this stage of the maneuver, the power to practically ground Aggressor aircraft by raids on Aggressor's installations.

D-day - 2:

On April 26th, the United States Air Forces flew a total of 44 missions as apposed to Aggressor's 12 missions. A total of 200 sorties were flown this date by United States Air Forces, of which only approximately 70 sorties were against Aggressor air and air installations. This did not appear to be as great a number of air base strikes against the Aggressor as would have occured in actual warfare; however, the variance of missions undoubtedly gave personnel involved better training.

D-day - 1:

On April 27th, the United States Air Forces flew a total of 58 missions; and Aggressor Air Forces 13 missions. The U.S. Air Forces continued attacks on Aggressor air with a considerable percentage of his available forces used for interdiction tactics. The Aggressor Air Forces applied most of his available forces against United States air installations, which were a very lucrative target indeed, as the aircraft to take part in the airlift to follow were being marshalled at their bases.

D-day:

On April 28th United States Air Forces employed the bulk of their combat strength in support of the airlift of parachute and air-transported troops into the airhead. A total of 85 missions was flown by United States Air Forces as opposed by 16 missions flown by Aggressor. Aggressor continued to place most of his effort against the lucrative targets at Maxton and Greenville. Air Cover was flown for the troop-carrier formations, and air support was evident throughout the day. Close air support for the ground troops was called for and received by parachutists soon after their landings in the Mackall and Holland drop areas.

COMMENTS BY BRIG GEN J. HIGGINS, CHIEF UMPIRE - Cont'd:

At 0900 hours the 187th RCT air-dropped on DZ Luzon-Rhine, and by 1158 had secured the Mackall Airfield. The airfield became operational at 1300. At this hour the advance elements of the Carolina Base Section arrived, closely followed by the 511th RCT. Later in the evening the 504th RCT of the 82nd Airborne Division began to arrive, and continued until late evening.

At 1600 hours the 505th RCT air-dropped on DZ Holland, and attacked south and west to assist elements of the air-landed RCT's in exiting from the causeways crossing a similated swamp between the Camp Mackall-Fort Bragg reservations.

Two G-18 gliders, three assault-type transports, C-122, C-123, and C-125 and the giant transport C-124 arrived at the Mackall airfield during the day.

The mission of the 187th RCT was to secure the Mackall Airfield; subsequently to seize the west exits of the causeway and expedite the rapid crossing thereof by the 511th and 504th air-landed RCT's. The mission of the 505th RCT was to secure the eastern exits of these causeways, and to provide security for the debouching of the air-landed RCT's.

Artificialities dictated the time of arrival of the first transport at Mackall airfield, and no conclusions can be drawn from this particular action. However, it is the opinion of the Umpire Group that in planning future operations adequate time must be allowed for the capture of the field, for its immediate repair to the extent that it will support aircraft of the C-54 and C-74 type, and for adequate protection of the field against subsequent Aggressor retaliatory action. It should also seem advisable to stage in field operating personnel to insure that all installations are set up and the airhead fairly well organized prior to the arrival of a large number of transports bearing troops and equipment. The initial confusion in the airhead indicates that one individual must be designated as the airhead commander, empowered to render decisions on and command all personnel in the airhead. His functions should be similar to that of the beachmaster in an amphibious operation. Troops delivered, 6657, vehicles and major weapons, 265, Cargo, 1126 tons.

D plus 1:

On April 29th, the United States Air Forces were able to lift supplies into the airhead without serious opposition, and they could therefore devote considerable of their strength to attacking the battle area. On this date, however, the U.S. Air Forces suffered what was probably their greatest single loss during the maneuver, due to the attack by Aggressor on the marshalled aircraft at Maxton Airfield. Umpire scoring indicated a loss of 13 United States aircraft, on this date.

On the ground side elements of the 187th and 511th RCT made contact with the 505th RCT, clearing the causeways and preparing the way for the link-up of additional troops and supplies from the airhead at Mackall.

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COMMENTS BY BRIG GEN J. HIGGINS, CHIEF UMPIRE - Cont'd.

After relief of elements of the 505th RCT in the 11th Abn Div area, the two divisions attacked to the east in their zones of action. Heavy equipment and supplies continued to be flown in, and several service units arrived to strengthen the airhead. Troops delivered, 3678; vehicles and major weapons 811; cargo, 1890 tons.

The movement of troops on D plus one was noticeably slow, due to the long period that many had gone without sleep. Furthermore, there appeared to be a tendency to carry too much non-essential equipment, including heavy blanket rolls. Many vehicles, especially trailers, carried such items as tables, chairs, records chests, etc. which might well have been brought in at a later date. Every effort should be made to curtail non-essential empedimenta in the assault units; all available space should be taken up by additional rations, gasoline, and ammunition.

D plus 2:

Air action on this date was limited to a certain extent by bad weather, except for the airlift. Aggressor planes were unable to fly, but U.S. Forces fighters carried out a few missions.

At 0630 hours the 325th RCT air-dropped on DZ Sicily-South with the principal mission of securing the high ground to the SE of the DZ. After suffering an initial set-back by Aggressor tanks and infantry, they secured their objective in the vicinity of the intersection of Street and Long-street roads. Remaining elements of V Corps continued to press forward against Aggressor delaying tactics, and Pope Field was captured by the 504th RCT at 1545 hours. Troops delivered, 3478; vehicles and major weapons, 656; cargo, 1726 tons.

The air-drop had fighter protection during the flight in, but weather was marginal and a short time after the drop was completed closed in to the extent that close support for the ground troops was impossible. It was at this time that Aggressor launched a strong tank attack, with U.S. Forces severely handicapped by lack of planes in the air. Close support for U.S. Ground Forces by the U.S. Air Forces worked well on many occasions, and there were several instances where planes delivered requested fire within three minutes. However, there were also several instances where coordination was lacking, and close support could not be rendered. Further training on the part of both Air and Ground Forces is indicated to iron out still-existing difficulties. Further, continued thought must be given to methods of combatting tanks without the help of planes in situations of this nature--there will be times, because of adverse weather conditions, when overwhelming air superiority will be of limited assistance to ground forces. Initial results of close support by fast flying jets is very encouraging, and it is felt that such aircraft are CAPABLE of performing such missions well.

D plus 3:

Again, adverse weather conditions severely limited air action, and relatively few strikes were carried out by opposing forces. The airlift was interrupted for three hours by severe weather.

COMMENTS BY BRIG GEN J. HIGGINS, CHIEF UMPIRE - Cont'd

On the ground side all elements continued to press forward, and in the 82nd area began to dig in on a defensive position assigned by V Corps. Active patrolling was carried out and attacks by Aggressor Forces repulsed. Orders were received to launch a coordinated attack by both divisions on the morning of D plus 5 in order to seize Fayetteville Airport, (simulated).

D plus 4:

Adverse weather conditions continued to hamper air activities. United States Air Forces were very fortunate during the last three days of the maneuver in that the majority of missions scheduled by Aggressor were cancelled due to bad weather at Aggressor bases. From the Umpire standpoint, and I am sure also from the Maneuver Commander's standpoint, the bad weather was unfortunate, in that the degree of effectiveness of fighters against an airlift of this nature could not be accurately determined. It was only for a very brief period of time in the early morning of May 2 when an AD Navy night fighter engaged the air stream that the umpires were able to arrive at some conclusions. This particular night fighter, by authenticated reports, intercepted thirteen transport type aircraft. During the course of this action he was also credited with destroying a United States night fighter. The umpires, however, due to artificialities involved could not rule this number of aircraft destroyed, but it does point out possibilities which should be carefully studied.

Ground action on this date was limited to adjustments of defensive lines by the 82nd Airborne Division, and by seizing of the assigned jump-off positions by the 11th Airborne Division. Intermittent clear weather in the battle area permitted several ground support missions by U.S. Forces, and the majority were well executed.

D plus 5:

The airlift continued, building up supplies at both Mackall and Pope Airfields, many more service elements of the task force were brought into the airhead at this time. Troops delivered to the airhead on D plus 4 and on D plus 5 to conclusions of exercise at 1000 hours, troops, 4109; vehicles and major weapons, 916; cargo 5561 tons.

V Corps launched its three division attack (The Third Infantry Division was brought in for CPX participation during the last twenty-four hours) at 0800; the attack progressed well, units reaching their respective restraining lines in three to four hours, and the problem was terminated at 1000 hours.

SUMMARY

1. The Berlin Airlift type of logistical support for an airborne operation is feasible, with the limitations that a very high degree of air superiority be obtained and held, that the airhead be firmly secured and runways

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COMMENTS BY BRIG GEN J. HIGGINS, CHIEF UMPIRE - Cont'd.

be in shape to receive heavy transport planes, and that adequate time is allowed for the installation of control and operating personnel and equipment prior to the arrival of transport planes in large number and at short intervals. It is especially adaptable to the build up of type supply such as food, gasoline, and ammunition. Generally speaking, this type of supply accounts for 90% of the logistical support of combat action, once personnel, weapons, and transportation are in.

2. Airlift operations of the Berlin Airlift type must be made flexible enough to meet the threat of enemy action at the terminals and enroute. In the initial phases many interruptions can be expected, such as enemy ground raids, air raid alerts, etc. Enroute, unless provision is made for changes in routes periodically, mobile anti-aircraft artillery weapons will take an excessive toll. The effect of enemy night fighters on the air stream must be carefully evaluated.

3. The present commercial type transports, the C-54 and the C-74 have performed well, but lack of ability to transport bulky tactical equipment limits their efficient employment in the early stages of an airborne operation. The C-119, now replacing the C-82, has been warmly received by the ground combat troops, and can be said to have passed its first mass employment test with flying colors. There is a very definite need for assault type transports capable of landing on unprepared fields or roads close behind the assault troops.

4. It is believed that a much better estimate of the effect of "red alerts" would have been obtained had all troops played the problem seriously. Even if the commander is willing to accept risks in working his personnel when air attacks are imminent, due to the urgency of his mission, it is extremely doubtful that men will remain on the job under actual "red alert" conditions. This factor is also worth of careful evaluation in estimating the efficiency of operation of an airhead under constant air threat.

5. The umpire staff is of the opinion that actual dispersal of aircraft, to the degree permitted by the nature of the air bases and the number of aircraft involved, should have been played. Both the ceasing of work during "red alerts" and dispersal of the aircraft involve a time element which to a considerable degree affects the airlift mission.

6. U.S. Air Forces pilots were fooled on many occasions by the Aggressor air controllers and were directed to attack own friendly targets. It would appear that this was due to either poor intelligence information available to U.S. Air Foces, or to poor briefing of the pilots.

7. Many umpires and observers have remarked that quite a number of the personnel involved in this exercise did not appreciate the fire power of the modern fighter airplane. It is recommended that prior to engaging in a maneuver of this type that a demonstration of air power destructiveness be staged. Such a demonstration of the ground weapons of the airborne troops was presented on a small scale prior to this maneuver, and their effect demonstrated to all ground and air umpires.

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COMMENTS BY BRIG J. HIGGINS, CHIEF UMPIRE - Cont'd:

8. The mechanism of air umpiring is extremely complex. Simulated fire power, the necessary safety rules, and the artificialities injected into the problem made accurate damage assessment very difficult. We have much to learn in the business of air umpiring. It is strongly recommended that this problem be made a project to be pursued at a high level, possibly under the jurisdiction of the Air University.

9. Combat effectiveness on the part of the individual soldier can be considered excellent, but cannot be so considered insofar as our units are concerned. Our units are understrength, and until such time as the squads and platoons are brought up to full strength we cannot say that our units are "ready". However, it is believed that the framework of these units is sound, and filling the vacancies with well-trained basic soldiers would permit both airborne divisions to be in a satisfactory state of combat readiness within a relatively short time.

10. The success of the heavy equipment drops has been highly gratifying, and leads us to believe it may solve the present pressing problem of prividing long range anti-tank protection for the parachutist. Reconnaissance capabilities of parachutists are also tremendously increased.

11. The performance of the airhead logistical units, as organized by the Carolina Base Section, has been excellent, and it is believed that further tests will develop a special or airport unit organized to meet the unique requirements of an airborne operation.

GENERAL

In considering the simulated personnel casualties and materiel losses, it must be kept in mind that a very high percentage loss has been brought about by situations deliberately injected by the umpires. Aggressor has advantages that, aided by the umpires, permit him to anticipate and meet every U.S. Force thrust with ease, and to time his own attack when they would be most disastrous to U.S. Forces. It is my considered opinion that under actual battle conditions, with U.S. Forces intentions and dispositions normally hazy to the enemy, personnel casualties and materiel losses would not have been as heavy as our umpire records show. We have been purposely severe in assessing penalties in order to impress lessons on U.S. Forces. I am glad to say reports from the field indicate that this has not reduced aggresiveness one iota--rather, it has intended to make the airborne soldier even more determined to prove to aggressor that he learns quickly and only asks a chance to get another crack at him.

One of the outstanding features of the entire exercise was the spirit of cooperation displayed by all services, at all levels of command, and at all localities. It was especially gratifying to observe the speed with which representatives of the various services got together to work

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out problems which arose, and many difficulties were solved by on-the-spot agreements by the working personnel and promptly confirmed by the various headquarters concerned. There were, of course, many an argument and disagreements over minor points, but they were invariably brought about by honest differences of opinions; once settled, everyone cooperated. Also, and this statement appears again and again in my umpire reports, there was an obvious desire on the part of all participants in this exercise, from the recently-joined recruit to the senior commander, "to do a good job." By and large, there was a minimum of official buck-passing and of personal passiveness--the underlying spirit seemed to be an honest desire on the part of everyone to pitch in and work hard for a common cause. The unusual nature of this exercise may have been one of the principal reasons for this attitude, but regardless of motives this maneuver was certainly unique in this regard.

In my humble opinion, Exercise Swarmer has been highly successful. We have had many triumphs, and disappointments. We have learned a great deal, and we have obtained information on many points that may lead us to successful solutions of many problems confronting us. Above all, we have learned to work together for a common cause, and honest discussions of controversial points should enable us to provide for as many exigencies as possible, to the end that airborne operations of the future may be mounted with smoothness and dispatch, and minimum casualties.

CLOSING REMARKS

I would like to take this opportunity, at the close of my portion of the critique of Exercise Swarmer, to express my appreciation to the Maneuver Commander and his staff for the loyal support afforded the Umpire Group; to the Commanding General of Fort Bragg and his staff for their assistance in obtaining personnel and materiel necessary for our umpire set-up; to all tactical commanders, staff, and other personnel for the opportunity of working with you in the field and in garrison; to Aggressor, as represented by many units, for the fine spirit and splendid work in carrying out a most difficult assignment; and to my own very understanding and able staff and corps of umpires for their outstanding contributions toward making Exercise Swarmer a success.

COMMENTS BY MAJ GEN ROBERT M. LEE, COMMANDER, AGGRESSOR FORCES

The major elements of the aggressor force consisted of an aggressor headquarters with a commander, a chief of staff, and deputy chiefs for Army, Navy and Air Force who had a very few officer and enlisted helpers. Practically all chiefs and no Indians. This group with the able assistance of the Chief Umpire directed Aggressor operations.

The ground force was built around the 15th Infantry RCT (less the First Battalion), Third Infantry Division from Fort Benning, Georgia. Major attachments were:

The 41st Field Artillery Battalion
The 44th Heavy Tank Battalion and
The 70th Anti-aircraft Artillery Battalion.

The Air Units originally consisted of the 31st Fighter Wing with the following units attached for operations:

31st Fighter Bomber Group from Turner Field, Ga., and the 82nd Sq of the 78th Fighter Group from Hamilton Field, California, totaling 66 F-84 aircraft. Three days after the start of air operations this was reduced to 25 F-82's.

162nd Night Photo Squadron from Langley - 16 B-26 type bombers and photo aircraft.

A Navy Composite Squadron from VC-4 Squadron at Atlantic City, N. J., with 9 F-40's, 3 AD-2's and on P2V aircraft.

Air control, and coordination of Air and Ground Units was achieved by a Joint Operations Center and Tactical Air Control Center located at Aggressor Hq on the eastern edge of the Fort Bragg reservation, a Tactical Air Direction Center located at the Fayetteville, Grannis airport and two Tactical Air Control Parties disposed, as required by the air-ground plan, with the elements of the 15th Inf. This Tactical air control system was provided by the 606th Aircraft Control and Warning Squadron of the 502nd Tactical Control Group augmented by personnel from the Army, Air Force and Navy at large.

Briefly the mission of the AGGRESSOR force for this exercise was three fold -

1. To train and evaluate the training proficiency of, the units assigned by the maneuver commander.

2. In cooperation with the chief umpire, and as a training aid for the maneuver commander, to direct the action of the elements of the AGGRESSOR force in a manner to achieve the maximum training of the U. S.

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COMMENTS BY MAJ GEN ROBERT W. LEE, COMMANDER, AGGRESSOR FORCES - Cont'd:

Forces in the accomplishment of their mission.

3. To study and evaluate the most effective methods of counteracting an enemy airborne assault, enemy resupply and a continuing enemy airlift.

General speaking it is believed that to various degrees, the missions were accomplished. During the training phase of the maneuver, the air units flew 775 hours in preparation for air operations. Control elements were shaken down. The ground elements spent many battalion days digging up the Fort Bragg Game Preserve in preparation for a task which might logically be assigned to a force three times the size of the actual force. I might say this was accomplished without the loss of a single one of General Hodges turkeys or deer.

The operations during the tactical phase of the exercise were carried out according to plan with the exception of air missions after D-Day. From the 29th of April, D plus 1 thru the end of the exercise, Aggressor was able to get only 10 effective sorties into the maneuver area because of continuous bad weather conditions at the aggressor air bases, Langley and Norfolk Naval Air Station. The limited operations of Aggressor air on and after D-Day certainly underscored the requirement for almost complete mastery of the air in the area by a force establishing an airhead of this type. It is regretable from a standpoint of the lesson that might have been learned, that this condition was established by the weather, not in the airhead area but in the area from which aggressor aircraft were forced to operate.

In the ground action, significant aggressor successes were accomplished by coordinated groupings and short attacks or counter-attacks by the Infantry-tank-artillery team, then regroupings in preparation for sharp strikes against subsequent threats as they might occur. Mobility of all aggressor ground units, superior communications within those units and ration of 30 minutes sleep per man per day for seven days were the keynotes to the ability of the small aggressor ground force presenting any worthwhile opposition to the U.S. Forces.

Deception both in the air and on the ground played a significant part in aggressor operations. Until tanks were committed on D-Day, pneumatic dummies drew the bulk of U.S. air attacks on such targets. Skillful establishment of dummy artillery and anti-aircraft artillery positions and night displacements to previously prepared camouflaged positions prevented occupied positions from being discovered and effectively attacked by U.S. artillery and air until D plus 3.

On D plus 1 and D plus 2 when Aggressor Air was grounded because of

COMMENTS BY MAJ GEN ROBERT M. LEE, COMMANDER, AGRESSOR FORCES - Cont'd,

fog and rain at its bases, several U.S. air formations were taken under the control of an agressor forward ground controller. Attacks were directed against U.S. forces with pilots reporting good results, flight leaders were kept occupied attempting to get proper authentication for transmission until fuel was too low to remain in the area longer, and flights were diverted from their original missions.

In summary I feel that all aggressor units gave their best to provide the maximum possible training under the circumstances, for the U.S. Forces; received invaluable training themselves; and are leaving Exercise STA[illegible] with a feeling that during the past month, much has been accomplished.

COMMENTS BY BRIG GEN PAUL F. YOUNT, CAROLINA BASE SECTION

In presenting the logistics part of the critique, I am going to eliminate any comments that deal with single staff sections or technical services and discuss only lessons of general interest. There are seven points set forth on this chart which I believe are the major items of general interest that were high lighted during Exercise SWARMER.

NEEDS

1. Logistic planning to preced tactical planning.

2. Doctrine on Joint command at:

   a. Ports of Embarkation
   b. Ports of Debarkation

3. Doctrine on joint logistics in an airhead.

4. Establishment of Movements Control as J-6.

5. Joint military documentation for the Department of Defense.

6. Standardization of air transportability training in the Army and Air Force.

7. Independent communications for the logistical command.

The first item is one that I want to repeat even at the expense of being somewhat boresome as I have said it in every conference thus far - specifically "Logistics Planning to precede Tactical Planning". I believe the accuracy of that finding is now accepted. There have been many instances in which Tactical Planning in this Exercise has had to be revised due to the impossibility of providing proper logistical support to tactical operations. There probably is no place in which the necessity for close logistical support is more apparent than in connection with Airborne operations such as Exercise SWARMER. Actually, logistics planning should be concurrent and coordinate with the strategic planning preceding such an operation.

The second need demonstrated is for "Doctrine on joint command at: a. Ports of Embarkation, b. Ports of Debarkation." I have listed these two parts separately since in my judgment they are different problems. In both places it is essential that there be unity of command on a joint basis, if smooth functioning is to be assured. In the case of the Port of Embarkation I think further study is necessary before making specific recommendation as to the service exercising the joint command authority. However, that part of the command controlling the movement of Army personnel, equipment and supplies, and the loading,

COMMENTS BY BRIG GEN PAUL F. YOUNT, CAROLINA BASE SECTION - Cont'd:

lashing and documentation, should be an integrated unit under an Army commander reponisble to the joint commander. In the Ports of Debarkation, I believe that only one commander can be considered in the assault phase and that is the tactical commander of the Army. In the second phase after the airfield is secured and the build up has commenced there is still a predominance of Army interest whereas the Air Force role is that of a carrier and not that of a base operator. The personnel and cargo movements are almost entirely matters of Army interest. Therefore it is believed that the joint command should be vested in the Army throughout both the assault and the build up phases.

The third need is for "Doctrine on joint logistics in an airhead." Within the period covered by Exercise SWARMER there were no significant requirements for Air Force logistical support. However, with the build up of fighter strength such a need would develop. It is not believed that the services could afford the luxury of two independent logistics commands in the early phases. Therefore, it is believed that we should develop doctrine on joint logistics where common items are involved, not of course where air technical supply is involved.

The fourth need is the "Establishment of movements control as J-6," in accordance with current doctrine taught at the Armed Forces Staff College. Initially the movements program was to be prepared by means of a teleconference under the guidance of J-4. It became apparent prior to action that the movements control function in connection with an airborne or air supply operation had to be extremely flexible and a continuous in order to be responsive to tactical needs. Accordingly, a permanent committee called the SWARMER Airlift Planning Agency was established under the supervision of J-4. Thus, the committee did not have authority to take final action in the name of the Task Force Commander. In my opinion, it should have been organized as an independent joint staff function with its head (J-6) empowered to act for the Task Force Commander. I believe that the importance of movements control is so great due to the time factor in air operations, that this action is essential.

The fifth need is for standardization of "Joint military documentation for the Department of Defense." In Exercise SWARMER we found multiplicity of documentation due to variation in usage between the airborne elements of the Army and the Air Force. The Carolina Base Section adopted Air Force forms 95 and 96B as being the best available for our purposes. However, these forms are by no means ideal and it is recommended the whole matter of documentation be studied on the level of the Department of Defense in order that all services use common documentation.

The next need demonstrated was for "Standardization of air transportability training in the Army and Air Force." Wide discrepancies were developed between Army and Air Force doctrine and regulations. Existing Army training publications are at variance with Air Force regulations and should be revised. A specific recommendation in this connection is that the Air Materiel Command have authoritative representation at all air transportability schools so as to insure that joint doctrine is developed which recognizes the needs of tho Army and the essential safety requirements of the Air Force.

The seventh need is for "Independent communications for the logistical command." While the lack of such communications in Exercise SWARMER was the result of shortage of Signal Corps personnel to install and operate such communications, the impact of their absence was quite apparent. Proper logistics support and control of movement are impossible when the logistics commander is dependent upon an already overloaded tactical net for communications with the depots, airports and airheads.

As I have said, these are points of general interest only. Items of specific interest to various staff sections and technical services will be covered in the final report. However, I would like to stress the point, in connection with this critique, that the concept of air supply developed in connection with SWARMER is applicable not only in connection with parachuted assault operations such as characterized SWARMER, but is equally applicable to supply of an isolated element of a command, such as occurred with the 14th British Army in Burma.

During Exercise SWARMER, the 7th Transportation Medium Port, with minor augmentation of officers only, was used as the parent unit for Headquarters Carolina Base Section and the four ports. The strength of this organization is inadequate to support that number of headquarters during a war time operation. The unit served successfully in this Exercise since the period of operations was short and in addition many of the functions that would be exercised by a base section in time of war, especially the direction of Engineer and Signal Corps service functions, were missing. One solution to this would be the use of a Transportation Major Port (TO & E 55-110-1) with its greater strength and capabilities. Still another solution may be the use of the Logistics Command if the composition and utilization are developed along the present pattern of thinking. However, even though the Logistics Command is used to staff the Base Section, the Transportation Ports should be utilized to staff the operation of aerial ports of embarkation and debarkation.

As you know, the Carolina Base Section was formed late in the Exercise. As a result, all the initial planning was carried on by the staff of the V Corps, and their cooperation and support subsequent to the formation of the Carolina Base Section was most helpful and contributed much to the success of the Carolina Base Section.

COMMENTS BY BRIG GEN PAUL F. YOUNT, CAROLINA BASE SECTION - Cont'd:

The only unsatisfactory part of the entire maneuver is that I cannot honestly make a single derogatory remark about the Chief Ump or his subordinates.

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COMMENTS BY MAJ GEN P. W. CLARKSON, U.S.A.

Exercise SWARMER was essentially an airborne operation, the principal objective being to seize and establish an airhead with airborne forces, and to establish a Berlin type airlift to supply the ground forces through the airhead. Therefore, my comments, with that in mind, are confined to matters relating to that objective. After all, the purely ground forces combat operations developed little that was new. It did provide valuable training for commanders and staffs, and troops. The ground exercise did much to provide training to overcome the very deficiencies that were disclosed.

For planning, time was too short. It seems it always is, both in maneuvers and in actual operations. We must expect to work under presure.

In preparation for an airborne operation, for best results, a few of all types of aircraft to be used, should be provided in advance for training of troops who are to load and unload these craft.

Bulk supplies must be made more realistic. It was too easy in this operation to divert airplanes hauling simulated supplies to handle actual supplies which were behind schedule. All simulated supplies should be represented by sacks or boxes of sand of proper weight.

Port of debarkation units organized like the Shore Party in an amphibious operation should be developed. The Engineer Special Brigade, Boat and Shore Regiment (less boat elements) could well be used for this purpose. It should bring in an advance party with assault troops and the remainder in the first planes to land.

Forward Air Controllers worked well in the operation and did direct air strikes in support of front line troops. For best results, FAC's and TACP's should be assigned to duty with assault troops 3 to 4 weeks prior to D-Day.

In this exercise, as in all exercises in which I have been involved, many communication difficulties were encountered. Most of these are not equipment deficiencies, nor lack of maintenance personnel and maintenance equipment, but are due primarily to lack of trained operators and users - mostly the users. Air and wire circuits are cluttered with too much unimportant traffic.

There was too much waiting around at embarkation ports by troop units after receiving port calls. One unit was called to the embarkation port and waited over 15 hours before embarking aboard planes. It was, of course, one of the purposes of this exercise to determine the causes of such delays and to develop a system which will avoid them.

Publications are available which set forth the capacities and

COMMENTS BY MAJ GEN P. W. CLARKSON, U.S.A. - Cont'd:

capabilities of the various aircraft. In many cases it was only after a great volume of work had been done in planning that new actual or maneuver capabilities were determined. Aircraft capabilities as listed in Air Transportability publications should be revised and kept up-to-date. These publications should also set forth peace-time or maneuver special limitations on allowable lift of each craft. It is essential that platform scales be provided at ports of embarkation to weigh vehicles as they come in and, whether or not the load is suitable, should not be left to the determination of the individual pilot. An Air Force Port Inspector, or similar official, should make this determination.

Tactical air support was available in quantities far in excess of what a Corps could expect. The air-ground liaison worked through forward air-controllers and front line troop units were loud in their praise of the prompt, heavy support provided throughout the problem. I would recommend a training exercise using live ammunition, stationary and moving targets representing tanks and other likely weapons, with Forward Air Controllers, TACP's and Infantry company and battalion commanders present. Let's satisfy ourselves on the one point not demonstrated in this exercise, but that we believe can be done - that support aircraft, on call from FAC's, can locate exactly, hit, and destroy what the front line commander wants knocked out.

I should like to say in conclusion that this has been a most valuable training exercise to all who participated; it has developed much factual information in regard to an airborne, air-supplied operation, and it has brought the Air Force and the Army close together in appreciation of each other's problems and respect for each other's ability to do their job.

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REMARKS OF GEN W. R. WOLFINBARGER

I will open my remarks by complimenting the men of the Army, Navy, Marine Corps, and Air Force with whom I have worked, who by their enthusiasm and inter-force co-operation have made exercise SWARMER possible.

First - in my opinion the command organization, set up for SWARMER, was sound from every aspect. When lines of command and responsibility are as simply and clearly drawn as they were in this case, the tasks of subordinate units and their commanders are made immeasurably easier. The importance of this feature in a joint manouver cannot be over emphasized.

From the Air Task Force point of view, the high-light of the Exercise was the integration of Troop Carrier and Strategic Air Transport elements into a single Air Transport Force. It demonstrated to my complete satisfaction that Troop Carrier and Air Transport concepts are capable of successful combination and that the two elements, when jointly employed, logically and successfully complement each other in this type of an operation.

The Exercise has clearly shown that each force has a great deal to learn from the other and a simple, down-to-earth example will illustrate my point. A Troop Carrier precept is that a crew member is responsible for the loading of each plane. This is an excellent doctrine, to be sure, in a short operation involving only a few missions. But, on the other hand, the Strategic Air Lift people learned long ago that it isn't the answer for a sustained operation. Crew members must have their sleep, just the same as other people, and it is far more efficient to have a trained technician take over supervision and insure correct weight distribution in the aircraft. But the air lift people also learned that this job specialization does not lessen the necessity for multiple crews to get the highest possible utilization rate from asagined aircraft - and a high utilization rate is an absolute "MUST" for efficient operations of this type.

Our principal difficulties from the Air Transport point of view were attributable to some extent to the fact that the concept of the plan was changed to include a Strategic Air Lift after much of the basic planning had been completed. The commitment of MATS at a late date in the planning phase required last minute adjustments in earlier plans and entailed air movement of both Army and Air Force units and equipment from one base to another during the time that should have been utilized in firming up the details of the joint operation and indoctrination in Air Transport and Troop Carrier concepts.

Joint planning by all participating forces from the very inception of the plan is a prerequisite to the attainment of a degree of inter-service indoctrination that will allow clear-cut delineation of the responsibilities of each force and prevent misunderstanding after the operation begins.

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REMARKS OF GEN W. R. WOLFINBARGER - Cont'd:

Internally, the Air Transport Force ascribes some of its difficulties both to the inadequacy and lack of T O & E's. Troop Carrier T O & E's need revision for sustained operations. Traffic personnel, mechanics and flight crews must be added to a chieve greater efficiency in the use of their airplanes. And, if MATS is to engage in combat operations, it should have a T O & E. Further, it might be well to consider official recognition of this type of operation for MATS and include it in its mission and training curriculm.

On the Tactical Air side of the operation I would like to say that it was a gratifying experience to have sufficient aircraft available. All of you know that too often this ins't the case. But I can state that during Exercise SWARMER, with the exception of the times when we were grounded for weather, it was seldom that a request for tactical support of cover would not be fully met.

We consider the innovation of a full scale use of fighter pilots as Paratrooper - Forward Air Controllers to have been highly successful. In cases these "Air Force Infantryman" were calling down support aircraft less than ten minutes after they had jumped with the airborne battalions.

From the deficiency aspect, the Exercise has shown that we need airborne early warning radar for this type of operation, Completely successful air defense of an airhead or cover for transport aircraft cannot be attained with the present high speeds of fighter aircraft when the early warning radar is sited a hundred or more miles to the rear.

Finally, I believe there is much to be done in the establishment of air umpire techniques for future exercises. For one thing, we must have quicker and more accurate results of the days's sorties in order that we may pattern the next day's strikes on the previous day's operation.

Another consideration should be dependable utilization of umpire channels for relaying all changes in the play of the Exercise. I suspect you know that I am referring to the case of the artillery battery at Fort Bragg. It's a bit demralizing to find out at 2100 hours that 37 of your aircraft are blazing on the ground at Camp Mackall from artillery fire that started five hours earlier. Simulations are hard things to counteract if they are kept secret. We think we could have silenced that battery or at least dispersed our planes on the ground if we had just known we were being fired at - or for that matter, maybe we could have simulated knocking it out.

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COMMENTS BY LT GEN JOHN R. HODGE, TASK FORCE COMMANDER

Gentlemen: There was one characteristic of this maneuver which struck me as being entirely different from any maneuver I have ever seen. That was the prevailing spirit of brotherly love that existed throughout. Everywhere I went I found good relations between troops of Task Force SWARMER, the Umpires and Agressor. Included was a spirit of cooperative effort on the part of all, aimed at making the Exercise a success. I only hope that future exercises may carry the same spirit, since this is as it should be to get the best out of the hard work that goes into an exercise. This attitude was the result of several things. First, careful planning; second, careful and intelligent briefing of all hands; third, careful supervision of the Exercise, so that all phases were kept in balance; fourth, intelligent handling and use of Aggressor in its primary role as a training aid and not allowing the Exercise to get into an all out two-sided battle.

This maneuver was a bringing together, or a marriage, of several individual accomplishments that we knew we could do. Strategic airlift was operated in Berlin. We have demonstrated our ability to move equipment in troop carriers. We have demonstrated our ability to make mass tactical parachute jumps and drop certain heavy equipment from airplanes. We have demonstrated our ability to use tactical air in support of operations. We have demonstrated our ability to carry on ground operations after arrival in an airhead. Exercise SWARMER is the first time in a training exercise that we have joined together all these elements in one unified effort. There was no precedent for the planning of this type of maneuver. Naturally, there was considerable scrambling in the planning and setting up of some of the organizations to operate. Participation leaves no question but that operations into the airhead closely paralleled amphibious operations in many respects, and in some things we can use amphibious experience to a good purpose.

All of us must study continously the conduct of operations of this type. The full lessons of this maneuver cannot be covered in this critique, since the results of the Exercise must be carefully studied and analyzed and fully digested before we can reap the full benefits. We should have additional exercises of this type and should extend them to include operations over water, combined with amphibious operations and sea transportation as an integral part.

In our joining up of our known capabilities to make up this Exercise, we found several rough joints. We found some deficiencies in our organization and in our training to get the smoothest operation. For example, our troops of the Army have not had adequate training in air transportability - in actually using airplanes. Our use of air transport for equipment, supplies and personnel was in a great degree on-the-job training in this Exercise. Those who participated in it, I would say, are now proficient. We lacked proper organization for handling of

COMMENTS BY LT GEN JOHN R. HODGE, TASK FORCE COMMANDER - Cont'd:

supplies and equipment at the base and after arrival in the airhead. I think a study of what we used and results attained will give us a much better picture of our needs in this line and something to tie to in future planning. One definite must is an organization for early use in the airhead for handling of incoming planes with equipment and supplies. In my opinion, this should be similar to the Navy "Beachmaster" set-up. We must be trained to make more effective use of available air transport under tactical conditions. In other words, we must learn to marry up loads with organizations, so that we do not have any planes running partially empty. In this Exercise, we were unable to utilize anything like full plane capacity, due, in a great degree, to lack of experience in load dispatching. Under the best of conditions there will be some loss of efficiency where tactical considerations and combat loads govern, but we must make every effort to reduce that loss to the minimum. I am convinced that we can raise transportation efficiency under tactical conditions to as high as 80 to 85 percent of the plane capacity.

Before we become too enthusiastic about air-transportability as the final word in conduct of operations, I would like to point out that in this type of operation, with present equipment, we will be without tanks and without the heavy Engineer equipment that is so essential in repair of airfields and bridge operations. One other deficiency of the Army is the lack of a sure tank killer. It is my opinion that the proper use of tactical air support with the 5 inch rockets on the fighter-bomber can do a lot to overcome this deficiency. This means, however, is not effective during periods of bad weather and darkness. We must push a light mobile and effective anti-tank weapon which can be dropped from the air and give more thought to fully air transportable equipment of all types.

One of the outstanding features of the tactical air support was the splendid work done by the forward air controllers. I want to praise particulary those fighter-bomber pilots who volunteered to go to jump school and who jumped with the troops, carrying radios with which they contacted and controlled the airplanes in the forward areas. They did outstanding work. This, combined with the enthusiastic efforts of the pilots in the air, went a long way to establish the confidence of the ground soldier in his flying brother to give him the assistance that he needed. We must further develop and build up this confidence and teamwork.

In closing, I want to emphasize what to me was after all the outstanding thing about the entire Exercise. This was the high cooperative attitude and teamwork effort of everyone concerned. The ingenuity displayed throughout to overcome difficulties and the intelligent interest of every officer and man in the command was outstanding. Gentlemen, it is up to everyone of us here to be constantly on guard that we may be as good as those whom we command.

SUMMARY OF REMARKS OF LT GEN LAURIS NORSTAD

From the first date we started this maneuver, I have been impressed with the excellence of the maneuver staff. In preparation for this critique, I had members of the staff prepare 15 or 20 pages of notes. However, it appears these notes will not be needed inasmuch as most of the comments which were prepared have already been touched upon by the experts here.

As a preliminary remark I would like to emphasize what has already been stated during the critique this morning. An actual operation of the kind we have just run simply cannot be conducted unless we have clear air superiority. With this in mind, we entered this exercise with a high degree of assumed air superiority. In an actual operation I feel that an early movement of 12 or 16 fighter aircraft into the airhead at the time that the airhead is established will be absolutely essential in order to preserve the air superiority we will require.

My main comment is one that has not yet been touched on at length. It concerns the question of organization for a real emergency. We should be prepared to conduct an operation at least somewhat similar to the one we have just run. At the present time, one of our greatest deficiencies is the fact that a task force of this type does not actually exist in the field. I feel that elements of such a task force should be brought together. Accordingly, I intend to recommend to the Chief of Staff, U.S. Army, that, in my judgement, V Corps should actually be constituted as a tactical organization; that is, it should have under it the Army units that will make up a tactical corps in case of an emergency. I will recommend specifically that the 11th and 82nd Airborne Divisions, at least, be tactical units under V Corps. It would be a great advantage in having the 11th located geographically near the 82nd Division. However, for administrative reasons it might be necessary for it to remain where it is. I do not limit this concept to the 11th Division. Perhaps the 3rd Division should also be part of this corps.

The same principle holds on the air side. General Wolfinbarger's organization (TAF) must be built up. It is essential for it to be together under his control and in a position to balance the ground component of the task force. I intend to recommend to the Chief of Staff of the Air Force that this be accomplished. It would be of no value to organize one side of the task force without organizing the other. If the Army organized a tactical corps, it should be balanced by a tactical Air Force organization and vice-versa.

The second main point I have is on the air side and concerns the use of air transports in this type of operation. There remains a question of the efficiency of air transports in the operation of a strategic airlift. I am informed that we operated the airplanes we had at about 60 percent efficiency. Regardless of whether air transport operates at maximum efficiency or at 5 percent efficiency, its job in this type of operation is to meet the requirements of the ground organizations it is supporting.

SUMMARY OF REMARKS OF LT GEN LAURIS NORSTAD - Cont'd:

Within the air organization, I think that with a better utilization of air transport the number of sorties flown could be increased. Efficiency of operation from the air standpoint alone might be raised 10 or 15 percent. By analyzing and applying the lessons we have learned in this operation, we should be able to solve, at the beginning instead of the end of the operation, the problem of the most effective allocation. This would raise the efficiency of the operation as a whole and make more loads available. In this respect, there is at least the basis for suspicion that the tactics and technique are developments for the use of horse-drawn vehicles, early motor vehicles, and the train and the ship. I would like to see someone on the Army side analyze the airborne operations to see if it is possible to modify tactics to get more out of available aircraft. We are derelict in our duty if we do not analyze and endeavor to improve our efficiency. There will always be a shortage of transport type aircraft. Accordingly, we have to increase the efficiency of air transport and get more out of aircraft flown. I would suggest to the 82nd Division, V Corps, and the Airborne Training Center, that the tactics and timing of this type operation be carefully analyzed to see if we can increase efficiency 15 or 20 percent. Such an increase in efficiency would add the equivalent of another group to the operation. I do not believe we can carry out an expansion of our air transport force until we are sure we have done everything we can to maximize the utilization of what we already have.

This maneuver has pointed up, in the judgement of those most closely associated with it, the direction of future exercises. There is now under consideration the question of exercises with armored forces. One such exercise would involve the support of an armored force on the move. I hope this exercise will be approved. Another exercise which is indicated by the one we have just held would be one operated jointly with amphibious forces. It would be, in fact, a combination of an operation similar to Swarmer with an amphibious operation.

If major mistakes have been made in this maneuver, I am afraid I must claim a large share of the credit. To me, such mistakes are understandable since they were to some degree expected. I hope, however, that you people have found this exercise useful and profitable. We have learned, and will carry back to our particular fields of interest and activity, many useful lessons. I hope we will be able to apply them. I hope also that the lessons are not as bad as indicated by one of our national periodicals. One of the weekly magazines has stated that I am a member of the Ming Dynasty. That would indicate that I was a Chinaman. The only basis for this statement is that this exercise has been upside down and backwards. I hope you people haven't found it quite that bad.

Thank you for the enthusiasm with which you have entered into this problem. The most inspiring thing to me has been getting out to the field and seeing the men at work. They couldn't have worked harder if it had been actual combat. This springs from good leadership and the concentration of attention to the problem. When we study the lessons of this exercise you will find the reward for the enthusiasm you devoted to this maneuver.

Thank you all for the remarkable performance you have turned in.

END

1. GENERAL

a. One of the paramount objectives of Exercise SWARMER was a check to determine the adequacy of existing doctrine and procedures for the coordination of air and ground operations in the establishment and expansion of an airhead deep in enemy territory. Letter, Office, Chief Army Field Forces, Subject: "Testing of Joint Doctrine", 21 March 1950, directed that Commanding General V Corps, in conjunction with Headquarters Tactical Air Force (Provisional), test proposed chapters of the Joint Training Directive. Pertinent chapters were: "Joint Operations Center", "The Air-Ground Operations System", "Air Liaison Officers", "The Tactical Air Control System", and "Offensive Air Support of Airborne Operations".

b. The principle requirements generated by the cited directive were:

(1) Procurement, assembly and instruction of Army personnel for manning the Joint Operations Center and for employment as Ground Liaison Officers.

(2) Development of plans and procedures for receiving, processing and coordinating requests for air support; this included plans for support in early phases, prior to establishment of ground point to point communications within Divisions and between Divisions and the Joint Operations Center.

(3) Coordination of plans for air support with Corps, Divisions and supporting elements of the Air Force and Navy.

(4) Operation of a complete Air-Ground Operations System to implement the plans.

c. Army elements consisted of one (1) Corps controlling two (2) Airborne Divisions and one (1) Infantry Division. The Infantry Division was to have participated on a CPX basis; however, it did not actually enter the problem insofar as air support is concerned. Air Force elements consisted of Tactical Air Force (Provisional), operating the equivalent of nine (9) fighter-bomber squadrons (including Navy Air units and Air National Guard Units), one (1) Tactical Reconnaissance Squadron, three (3) Interceptor Squadrons and two (2) Light Bomber Squadrons. The Joint Operations Center functioned between V Corps and Tactical Air Force (Provisional).

d. Details of operations maybe found in the report of V Corps and in that of Air Task Force (SWARMER) of which Tactical Air Force (~~XXXXXXXXXXX~~ SWARMER) was a component.

2. SUMMARY OF EVENTS

a. The Air-Ground Operations Section submitted its estimate of personnel augmentation requirements for SWARMER to appropriate staff sections of Headquarters V Corps on 13 February 1950. These requirements were periodically reemphasized.

b. An AGOS officer participated in briefing and demonstrations covering general air-ground operations at the 11th Airborne Division, Camp Campbell, Kentucky during 21-25 March 1950.

c. On 23 March 1950, AGOS received four (4) of the five (5) proposed chapters of the Joint Training Directive mentioned in paragraph 1a above. Since planning for SWARMER had then been in progress for some little time, and since the ~~XXXXXX~~ provisions of the proposed chapters were to be implemented by 15 April 1950, the

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arrival of the proposed chapters at the relatively late date mitigated against their thorough assimilation and implementation by all agencies concerned.

d. All AGOS personnel then available for duty attended a preliminary briefing on SWARMER air operations, conducted by Tactical Air Force (Provisional) on 27 March 1950. An AGOS officer participated, presenting the enemy ground situation and friendly proposed plan for operations.

e. On 29 March 1950, G-3 V Corps directed that AGOS prepare an Air Support Annex to the Corps Operations Plan for SWARMER. AGOS prepared and coordinated the Air Support Plan, which became Annex 9 to Operations Plan Number 1, V Corps.

f. AGOS initiated, coordinated and participated in a briefing on air-ground operations conducted for SWARMER ground umpires on 6 April 1950. The presentation consisted of illustrated lectures covering all aspects of air support, starting with the initiation of a request at Battalion level, its processing through the Air-Ground Operations System, its coordination within the Joint Operations Center and including the control measures employed in directing aircraft to the target.

g. An intensive training program for augmentation personnel was initiated 29 March 1950. Typical subjects presented were:

Concept of and Operational Plans for SWARMER

Organization of U. S. Army

Organization of U. S. Air Force

Air-Ground Operations System

Air Force Combat Operations

Tactical Air Control System

Air Force Communications System

Air-Ground Liaison Signal System

Radio-Telephone Procedure

Duties of Liaison Officers

Instruction was prepared and conducted by augmentation officers, by permanent AGOS Officers, by Air Force Combat Operations Officers and by Officer specialists in appropriate fields. Instruction culminated in a one day CPX in which requests for air support were processed and recorded. Other concurrent commitments of permanent AGOS personnel, such as preparation of the Corps Air Support Plan, the short preparation period resulting from participation in Operation PORTREX, and the piecemeal arrival of augmentation personnel, were factors handicapping the conduct of the most effective instruction.

h. AGOS and CCS Officers presented a two hour briefing and conference on details of SWARMER air support plans for the 82nd Airborne Division on 12 April 1950 and for the 11th Airborne Division on 14 April 1950. Attendance included Commanders and Staff Officers of Divisions and of subordinate units including battalions and separate companies. Similar briefings for Air Force and Navy units concerned with Air Support were presented at a later date. A team consisting of an Air Force Officer, an Army Officer and a Marine Officer visited Oceana NAS, Shaw AFB, Congaree and Morris Fields and Langley AFB to orient all air units on details of the air support plan and on the army requirements for air support.

i. Ground Liaison Officers and their signal teams moved to their stations during period 13-15 April 1950. After

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orientation, they moved rapidly into their operational duties.

j. Elements of the air-ground operations section moved to the maneuver area on 14 April 1950. The G-2 Air Section became operational at 0600 hours 15 April 1950. G-3 Air Section continued on a training basis until 18 April at which time, processing of pre-assault counter air and deep interdiction strike missions was inaugurated. AGOS integrated the Corps Commander's desires in JOC planning for these operations.

k. V Corps, Tactical Air Force, 82nd Airborne Division and JOC, on 24 April 1950, conducted a CPX in three phases. In the first phase, air alert aircraft received requests from battalion Forward Air Controllers, simulating initial operations prior to establishment of ground point to point communications within the regiment. The second phase covered operations of air alert aircraft directed to Forward Air Controllers by Division Air Liaison Officers. The third phase brought JOC into play, processing requests received from the 82nd Division over facilities of the 20th Signal Company, Air-Ground Liaison. A time study, based on ten (10) mission requests reveals the following:

Average time to process request through Air-Ground Operations Section -4 Minutes.

Average time to process request through Combat Operations Section - 7.7 Minutes.

Average elapsed time between receipt of request and planes over target - 73.6 Minutes.

Maneuver restriction on fighter aircraft denied their use in the area occupied by the 11th Airborne Division. This unit employed liaison aircraft in lieu of fighter-bombers to accomplish the first two phases of the CPX.

l. AGOS assisted in the pre-operational phase training of Air Force units by selection of locations within the maneuver area to be struck as simulated targets. Requests for strikes were processed through the Joint Operations Center as a further training device.

m. Throughout the entire planning phase, the utmost coordination was effected with Tactical Air Force. This included joint conferences, orientations and detailed planing on such varied matters as training and placing of forward air controllers, preparation and distribution of Target Area Designator grid overprinted maps, and employment of Anti-Aircraft Artillery. In many cases, AGOS participation consisted simply in establishing contact between appropriate planners. In other cases AGOS participated actively in planning.

n. Operational phase.

(1) For operations, observations and recommendations peculiar to the G-2 Air sub-section, see inclosure 1 appended hereto.

(2) AGOS, concurrently with CCS, commenced full operations, on 21 April (D-7) (G-2 Air had been operating since 15 April). The G-3 Air sub-section operated in three (3) shifts as follows:

1st Shift 0500-1300

1 G-3 Air Action Officer

1 G-3 Air Duty Officer

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1 G-3 Air Records Officer

1 Operations NCO

1 Clerk - Typist

2nd Shift 1300-2100

Same as 1st Shift.

3rd Shift 2100-0500.

1 G-3 Air Action Officer

1 G-3 Air Duty - Records Officer

1 Operations NCO - Clerk - Typist.

Draftsmen on shifts were shared with G-2 Air.

This organization continued in effect throughout the operation, ending 3 may. Outgoing shifts remained on duty at the end of their tours sufficiently to orient the incoming shift. Overall supervision of all shifts was exercised by a senior G-3 Air Action Officer who was a member of the permanent AGOS establishment.

(3) For operations, observations and recommendations of Ground Liaison Officers, see inclosure 2, appended hereto.

(4) For operations, observations and recommendations of the Signal Air-Ground Liaison Company, see inclosure 3, appended hereto.

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c. Operations:

(1) Reconnaissance: See Inclosure 1.

(2) Strike: During the period 21 April - 3 May the Joint Operations Center received 212 pre-planned and 15 immediate request missions. Of the total 227 requests received, 152 were completely processed and laid on by the Air Force. The requests not laid on are broken down as follows: 20 were cancelled due to weather; 7 were withdrawn by Commanding General V Corps; 12 were cancelled because they duplicated other requests; 2 were cancelled after visual reconnaissance revealed no target; 25 were disapproved by the G-3 Air Action Officer; and 9 were disapproved by the Combat Operations Officer. Disapprovals by the G-3 Air Action Officer were based on targets being non-lucrative for air or of such low priority that the mission could not be executed with available aircraft. Disapprovals by the Combat Operations Officer were based on non-availability of aircraft or on CAA

administrative regulations prohibiting execution of the mission, e.g., low level attacks in populated areas. Of a total 2408 sorties flown by tactical support aircraft, 602, or 25% were flown in close support operations and 723, or 30% were flown on interdiction missions.

p. Redeployment phase.

Exercise SWARMER terminated at 1000 hours 3 May 1950. AGOS assisted in dismantling the field installations of the Joint Operations Center and administrative adjuncts. Personnel returned to Fort Bragg, prepared reports and participated in post-operations critiques and conferences. By 13 May, augmentation personnel were relieved and the AGOS was again reduced to its permanent personnel.

3. DISCUSSION OF PROBLEMS.

a. Personnel.

(1) The Air-Ground Operations Section established and presented its requirements for augmentation personnel, officer and enlisted, for SWARMER, on 13 February 1950. Requests were based

on provision for two (2) complete shifts and one (1) reduced shift at the JOC and for Ground Ln. Off Teams. Further, in the interest of disseminating accepted doctrine and procedures throughout the army, AGOS recommended that officer personnel be provided from army wide sources and consist of individuals presently, or in the near future expected to be engaged in air-ground operations. It was requested that personnel report for duty three (3) weeks before the exercise to permit proper training and development of teamwork.

(2) Several officers and enlisted men, whom it was planned would occupy responsible positions in the Joint Operations Center, arrived only after the installation moved to the field. Late arrival precluded adequate organization and training. The operation suffered accordingly, it being impracticable to conduct adequate training for personnel hitherto totally unfamiliar with air-ground operations and simultaneously carry out the required operational functions. Such concurrent training might be feasible if extended over a prolonged period; the duration of Exercise SWARMER dictated that pre-operation instruction be employed to ensure operational efficiency.

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(3) In addition to precluding the effective development of closely knit team functioning, the late and piecemeal arrival of personnel resulted in possibly lasting misapprehensions on the part of personnel as to the manner in which a well regulated Joint Operations Center functions.

(4) It is felt that the interests of the army, both operationally and educationally would have been better served in SWARMER, had adequate personnel been available early enough to have permitted proper orientation and team organization.

(5) See inclosure 4 for list of personnel participating in the Air-Ground Operations System for Exercise SWARMER.

b. Authority for selecting of Ground Targets:

(1) Tactical Air Force (SWARMER) provided aircraft on an air alert status for the army divisions throughout the exercise (the continued air alert status was required because the air-ground communications system failed, thus precluding the forwarding of immediate support requests - see paragraph 3c). Late on D-Day afternoon, reconnaissance aircraft sighted and reported a small group of tanks at a point approximately ten (10) miles distant from the nearest U. S. Forces near Camp Mackall airfield. The U. S. Forces consisted of a parachuted regimental combat team without heavy fire support weapons.

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Air alert aircraft over the U. S. regimental combat team provided the only immediately available heavy fire support. Due to a simulated swamp lying between the tanks and the U. S. Forces, tank movement was canalized; tanks could be kept under constant air surveillance. They constituted no immediate threat to U. S. Forces. Additional aircraft were due in the area within twenty (20) minutes.

(2) The G-3 Air Action Officer on shift, an armored officer, weighed the pertinent factors; realizing the possibility that other potential counter-attacking forces could well be concealed near the U. S. RCT, he recommended strongly that the air alert aircraft remain on their current mission, that the reconnaissance aircraft maintain surveillance over the enemy tanks and that the tanks be struck by the aircraft due to arrive in the area shortly thereafter.

(3) Commander, Tactical Air Force (SWAMP LR), despite the protests of the G-3 Air Action Officer, directed that the air alert aircraft be withdrawn from support of the U. S. RCT and strike the tanks. Fortunately, no counterattack developed in the area of the U. S. RCT; ironically, there is evidence that the tanks were rubber dummies.

(4) The basic principle at issue is whether air officers or army officers shall have the authority to determine the priority in which air effort is

to be applied in a ground support role. It is considered mandatory that the principle be determined which would establish the authority of the army commander to determine such priority, since his is the primary interest.

c. Communications.

(1) Details of signal operations will be found in inclosure 3.

(2) Further discussion on communication difficulties will be found in inclosure 1.

(3) (a) Typical of the delay encountered in transmission of important operational traffic over the facilities provided by the signal air-ground liaison company was the following message: "Chicken Road recommended as BSL for attack on three May one nine five zero". This message, classified secret, and given Operational priority precedence, was handed to the operator for the 82d Airborne Division at 1505 hours. It was received at JOC at 1753 hours, or two hours, forty eight minutes later.

(b) Eight (8) typical encoded messages, selected at random, averaging 239 words each, required an average time of seven hours fifty one minutes (7:51) between origin and readiness for delivery to addressee. Four (4) typical clear messages, selected at random, averaging 18 words each required an average time of forty

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five minutes (0:45) between origin and readiness for delivery to addressee. A time study based on these twelve (12) random messages will be found in inclosure 5.

(4) (a) Magpie (82d Airborne Division) and Sweepstake (11th Airborne Division), while located approximately fifteen (15) miles apart in the objective area could receive each other strongly and clearly, both on CW and on voice. Both could receive Elmer (JOC), located approximately thirty (30) miles away, strongly and clearly both on CW and on voice. Elmer (JOC) could receive both division stations only faintly on CW and scarcely at all on voice. Traffic between JOC and the divisions was virtually impossible. Nevertheless, Elmer's reception of GLO transmissions, both voice and CW, over distances varying between fifty (50) and four hundred (400) miles was excellent during most of the exercise.

(b) Communication failure between JOC and the divisions, rendered impossible the processing of immediate support requests. This, in turn, required that air effort be wastefully expended in maintaining an air alert status with aircraft immediately available to divisions through ground to air VHF communications. This status of aircraft on air alert was necessary throughout the exercise, simply because of inadequate communications insert.

(5) As indicated in inclosure 3, a total of 999 messages, with 91,967 groups (or word count) were transmitted and received over the facilities of the 20th Signal Air Ground Liaison Company at the JOC. Analysis reveals that this load could be reduced by careful screening of all messages; coding and decoding could thus be concurrently reduced. However, the rapidity of operations, with correlative limited permissable time for accomplishing such screening render meticulous screening somewhat impracticable. Further, with adequate equipment, the traffic could have been readily handled without delay.

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(5) A system requiring two hours and forty eight minutes to process a fourteen (14) word classified message from a division to JOC (paragraph 3c (3) (a)) and forty five (45) minutes to process and eighteen (18) word clear message (paragraph 3c (3) (b)), is totally inadequate to meet the requirements of an air-ground operations system for speedy, secure communications.

4. CONCLUSIONS

a. The preparation of V Corps Air Support Plan by the G-2/G-3 Air, JOC, violated doctrine as enunciated in the chapter "The Air Ground Operations System" to the proposed Joint Training Directive. This expedient, however, was necessary because requisite personnel for such preparation were not available elsewhere within the Corps headquarters. Thus, the best interests of the Corps were served by this use of JOC personnel.

b. The action of Commander, Tactical Air Force (SWARMER) in withdrawing air alert aircraft from support of troops at Camp Mackall in order to attack tanks beyond the simulated swamp is considered to have constituted a serious infringement on the prerogatives of the Corps commander, through his staff representatives, to determine priorities for support of ground troops. There is no evidence to indicate anything but the best of intentions on the part of the Air Force Commander in his action. His intense interest in his mission of supporting army troops was magnificent.

c. There were no other known violations of established doctrine in air-ground operations for Exercise SWARMER.

d. The requirements of an air-ground operations system for speedy, secure communications cannot be fulfilled by the signal air-ground liaison company as presently constituted and equipped.

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5. RECOMMENDATIONS

a. That, for future exercises involving participation of the permanently constituted air-ground operations section of V Corps, arrangements be made for its timely and adequate augmentation as may be necessary to fulfil its mission. Officer augmentation should constitute those individuals, army wide, currently or imminently to be concerned with air-ground operations.

b. That the equipment of the air-ground communications system be immediately reviewed to the end that operational requirements for expeditious and secure transmission of battle information be provided.

6. REMARKS

The permanently constituted air-ground operations section is continuing, in conjunction with representatives of Tactical Air Force (Provisional), the study and compilation of operational procedures, equipment and physical arrangements of the Joint Operations Center.

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JOINT OPERATIONS CENTER
AIR-GROUND OPERATIONS SECTION
POST EXERCISE REPORT - EXERCISE SWARMER

10 May 1950

1. Statement of problem:

The G-3 Air Duty Officer is one of three Officers assigned to each shift of the G-3 Air section of AGOS as it operates in a Joint Operations Center.

Purpose of Problem:

To test whether or not this office as so conceived is adecuate to the need of the G-3 Air section and if not to establish thru additions, deletions, and consolodation, an operating procedure that will best meet the requirements for such a duty under any and all circumstances and conditions.

2. Summary of events:

a. Chronological order: Not applicable to this duty.

b. General Description of Routine duties:

The G-3 Air duty Officer receives all requests for Air support other than reconnaissance requests and after checking each request submit it to the G-3 Actions Officer. He keeps all interested organizations from Army Group and tactical Air Command down informed through their respective GLO's of the bombline and its changes. He sends each midnight a Summary of G-2 and G-3 reports to all GLO's. He maintains the friendly ground situation on the ground situation map and he plots and simbolizes each target on the map as soon as the mission has been laid on. He assists the Records Officer whenever possible.

c. Detailed description of unusual operations, problems or equipment:

This office had never operated before; therefore it is not possible to say which are usual or unusual operations or problems. (Annex "A" details a new seating arrangement for the G-3 Air section that in the

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opinion of this observer would eliminate much uncalled for movement and confusion).

Communications completely failed. However the facilities as installed were ideal and if they had worked much that is now confused and not understood would no longer be a problem. The section was able to render assistance by the use of spot reconnaissance. These reports of enemy action were given direct to the Air Control Officer who was in direct communication with each plane aloft and he would direct the required aircraft to attack the target described in the spot report.

3. **Discussion:**

a. Opinion of reporter on facts:

The complete failure of communications precluded this office carrying out its primary mission - that of receiving strike requests and keeping the GLO's informed of the Army situation. However before the problem actually started (D-Day) communications did function and it was possible to detect errors in the seating arrangement of the section and a smooth, easy and quiet flow of information was impossible. (Annex "A" diagram explains this reporters solution to this problem).

b. Opinions of other observers on facts:

This reporter had no opportunity to interview observers regarding the operation of the AGOS.

c. Description of newly proposed improvements:

This reporter has no knowledge of any proposed improvements.

4. **Conclusions:**

a. Statement on adherence or non-adherence to accepted doctrine, procedures and techniques. Reason for non-adherence. Effect of non-adherence.

As stated above, this office had not been in operation before these manouvers and no accepted doctrines, procedures or techniques had been established. It is believed that the adoption of the recommendations of the 3 G-3 Air duty Officers submitting reports will be a basis for the establishment of procedures and techniques.

b. Statement as to whether or not problem served its purpose:

Problem did serve its purpose in that it provided a means to determine and to evaluate the misconceptions held prior to the beginning of the Exercise.

c. Statement as to whether or not full use was made of capabilities (Specific emphasis on AGOS capabilities) but including those of other elements of which reporter has accurate knowledge:

It is not felt that full use of the capabilities of the persons operating in the capacity of the G-3 Air duty Officer were made. Example: The duty Officer was not allowed to use plain common sense as regards mission requests. Two or more requests that obviously should be consolidated into one mission first had to be submitted, entered in the Journal and completely processed. They were later disapproved by the Combat Operations Officer as such and came back with the suggestion that they be consolidated into one mission. The reporter has no accurate knowledge of the capabilities of the other sections within AGOS or of other elements.

d. General conclusions:

It is felt that these in AGOS should have more information on the capabilities, functions, armor and ordnance of aircraft used by the Tactical Air Command. That all those within AGOS should be able to express an opinion to other army personnel on the proper type of aircraft to be used for a specific target.

5. Recommendations

a. Equipment:

It is recommended that the G-3 situation map be placed directly

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in front of the Duty Officer and that in addition to his regular telephone instruments he be given a headset that can be plugged in to any of the three circuits abailable. This will enable him to check the bomb safety line at the time a mission request is received. To plot targets as they come in and give him complete freedom of both hands.

b. Communications:

Circuits provided were ideal except they did not work. Alternate means of communications must be provided.

c. Coordination:

No recommendations.

d. Techniques and Procedures:

1. All units submitting mission requests be familiar with the operations of AGOS within JOC and if the requesting unit must have numbers for each request it is recommended that that number be assigned by the duty Officer.

2. That one copy of the submitted requests to retained by the duty Officer until the completed copy is returned by the Combat Operations O Officer. This will enable the duty Officer to check on the progress of requested missions.

e. Personnel and Administration:

Subordinates should take or be given instructions from one person only. This procedure will eliminate much of the confusion that was so much in evidence during this exercise.

F. Other:

No recommendation

JOSIPH G. SEARS
1st Lt. FA
G-3 Air Duty Officer

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ANNEX "A"

Top View

Actions Officer	
Duty Officer	Clerk
Records Officer	Clerk

Situation Map

Side View

G-3 Situation Map	
Open space for passing papers.	
Duty Officer	Records Officer

Mission request is received by duty officer, checked on map in front of him, request form accomplished, passed to clerk for entry in Journal and number, back to duty officer and then actions officer. If discussion is necessary between actions and duty officers it can be accomplished without either moving or undue noise. Actions officer hands or takes request to COS depending where the COS has his desk and when mission is completed the actions officer passes completed form to duty officer who in turn gives it to records officer.

The G-2 Air is as should be entirely out of this picture. It might be placed on line after the records officer of anywhere G-2 desires.

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JOINT OPERATIONS CENTER
AIR-GROUND OPERATIONS SECTION
POST EXERCISE REPORT - EXERCISE SWARMER

10 May 1950

1. Statement of problem:

The G-3 Air Duty Officer is one of three Officers assigned to each shift of the G-3 Air section of AGOS as it operates in a Joint Operations Center.

Purpose of Problem:

To test whether or not this office as so conceived is adequate to the need of the G-3 Air section and if not to establish thru additions, deletions, and consolodation, an operating procedure that will best meet the requirements for such a duty under any and all circumstances and conditions.

2. Summary of events:

a. Chronological order: Not applicable to this duty.

b. General Description of Routine duties:

The G-3 Air duty Officer receives all requests for Air support other than reconnaissance requests and after checking each request submit it to the G-3 Actions Officer. He keeps all interested organizations from Army Group and tactical Air Command down informed through their respective GLO's of the bombline and its changes. He sends each midnight a Summary of G-2 and G-3 reports to all GLO's. He maintains the friendly ground situation on the ground situation map and he plots and simbolizes each target on the map as soon as the mission has been laid on. He assists the Records Officer whenever possible.

c. Detailed description of unusual operations, problems or equipment:

This office had never operated before; therefore it is not possible to say which are usual or unusual operations or problems. (Annex "A" details a new seating arrangement for the G-3 Air section that in the

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opinion of this observer would eliminate much uncalled for movement and confusion).

Communications completely failed. However the facilities as installed were ideal and if they had worked much that is now confused and not understood would no longer be a problem. The section was able to render assistance by the use of spot reconnaissance. These reports of enemy action were given direct to the Air Control Officer who was in direct communication with each plane aloft and he would direct the required aircraft to attack the target described in the spot report.

3. Discussion:

a. Opinion of reporter on facts:

The complete failure of communications precluded this office carrying out its primary mission - that of receiving strike requests and keeping the GLO's informed of the Army situation. However before the problem actually started (D-Day) communications did function and it was possible to detect errors in the seating arrangement of the section and a smooth, easy and quiet flow of information was impossible. (Annex "A" diagram explains this reporters solution to this problem).

b. Opinions of other observers on facts:

This reporter had no opportunity to interview observers regarding the operation of the AGOS.

c. Description of newly proposed improvements:

This reporter has no knowledge of any proposed improvements.

4. Conclusions:

a. Statement on adherence or non-adherence to accepted doctrine, procedures and techniques. Reason for non-adherence. Effect of non-adherence.

As stated above, this office had not been in operation before

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these manouvers and no accepted doctrines, procedures or techniques had been established. It is believed that the adoption of the recommendations of the 3 G-3 Air duty Officers submitting reports will be a basis for the establishment of procedures and techniques.

b. Statement as to whether or not problem served its purpose:

Problem did serve its purpose in that it provided a means to determine and to evaluate the misconceptions held prior to the beginning of the Exercise.

c. Statement as to whether or not full use was made of capabilities (Specific emphasis on AGOS capabilities) but including those of other elements of which reporter has accurate knowledge:

It is not felt that full use of the capabilities of the persons operating in the capacity of the G-3 Air duty Officer were made. Example: The duty Officer was not allowed to use plain common sense as regards mission requests. Two or more requests that obviously should be consolidated into one mission first had to be submitted, entered in the Journal and completely processed. They were later disapproved by the Combat Operations Officer as such and came back with the suggestion that they be consolidated into one mission. The reporter has no accurate knowledge of the capabilities of the other sections within AGOS or of other elements.

d. <u>General conclusions:</u>

It is felt that these in AGOS should have more information on the capabilities, functions, armor and ordnance of aircraft used by the Tactical Air Command. That all those within AGOS should be able to express an opinion to other army personnel on the proper type of aircraft to be used for a specific target.

5. <u>Recommendations</u>

a. Equipment:

It is recommended that the G-3 situation map be placed directly in front of the Duty Officer and that in addition to his regular telephone instruments he be given a headset that can be plugged in to any of the three circuits abailable. This will enable him to check the bomb safety line at the time a mission request is received. To plot targets as they come in and give him complete freedom of both hands.

b. Communications:

Circuits provided were ideal except they did not work. Alternate means of communications must be provided.

c. Coordination:

No recommendations.

d. Techniques and Procedures:

1. All units submitting mission requests be familiar with the operations of AGOS within JOC and if the requesting unit must have numbers for each request it is recommended that that number be assigned by the duty Officer.

2. That one copy of the submitted requests to retained by the duty Officer until the completed copy is returned by the Combat Operations O Officer. This will enable the duty Officer to check on the progress of requested missions.

e. Personnel and Administration:

Subordinates should take or be given instructions from one person only. This procedure will eliminate much of the confusion that was so much in evidence during this exercise.

F. Other:

No recommendation

JOSIPH G. SEARS
1st Lt. FA
G-3 Air Duty Officer

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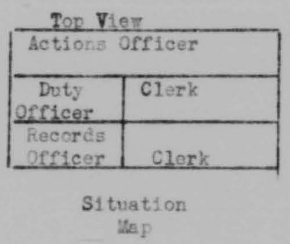
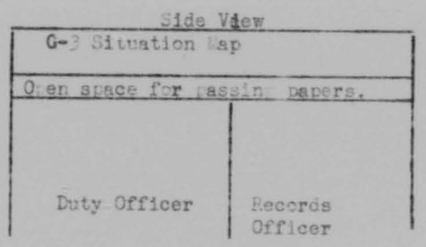
ANNEX "A"





Mission request is received by duty officer, checked on map in front of him, request form accomplished, passed to clerk for entry in Journal and number, back to duty officer and then actions officer. If discussion is necessary between actions and duty officers it can be accomplished without either moving or undue noise. Actions officer hands or takes request to COS depending where the COS has his desk and when mission is completed the actions officer passes completed form to duty officer who in turn gives it to records officer.

The G-2 Air is as should be entirely out of this picture. It might be placed on line after the records officer of anywhere G-2 desires.

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G-3 Air Duty Officer
Report on Exercise Swarmer

10 May 1950

1. Statement of Problem:

The G-3 Air Duty officer is one of three officers assigned to each shift of the G-3 Air Section of AGOS as it operates in a Joint Operations Center.

Purpose of Problem:

To test whether or not this office as so conceived is adequate to the need of the G-3 Air section and if not to establish thru additions, deletions, and consolidation an operating procedure that will best meet the requirements for such a duty under any and all circumstances and conditions.

2. Summary of events:

a. Chronological Order: Not Applicable to this duty

b. General description of Routine Duties:

The G-3 Air duty officer receives all requests for Air support other than reconnaissance requests and after checking each request submit it to the G-3 Operations officer. He keeps all interested organizations from Army Group and Tactical Air Command down informed through their respective GLO's of the bombline and its changes. He sends each midnight a summary of G-2 & G-3 reports to All GLO's. He maintains the friendly ground situation on the ground situation map and he plots and simbolizes each target on the map as soon as the mission has been laid on. He assists the Records Officer whenever possible.

c. Detailed description of unusual operations, problems or equipment:

This office had never operated before; therefore it is not possible to say which are usual or unusual operations or problems. (Annex "A" details a new seating arrangement for the G-3 Air section that in the opinion of this observer would eliminate much uncalled for movement and confusion).

Communications completely failed. However the facilities as installed were ideal and if they had worked much that is now confused and not understood would no longer be a problem. The section was able to render assistance by the use of spot reconnaissance reports sent in by pilots on routine photo reconnaisance. These reports of enemy action were given direct to the Air Control officer who was in direct communication with each plane aloft and he would direct the required aircraft to attack the target described in the spot report.

3. Discussion

a. Opinion of reporter on facts:

The complete failure of communications precluded this office carrying out its primary mission - that of receiving strike requests and keeping the GLO's informed of the Army situation. However before the problem actually started (D-Day) communications did function and it was possible to detect errors in the seating arrangement of the section and a smooth, easy and quiet flow of information was impossible. (Annex "A" diagram explains this reporters solution

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to this problem).

b. Opinions of other observers on facts:

This reporter had no opportunity to interview observers regarding the operation of the AGOS.

c. Description of newly proposed improvements:

This reporter has no knowledge of any proposed improvements.

4. Conclusions:

a. Statement on adherence or non adherence to accepted doctrine, procedures and techniques. Reason for non adherence. Effect of non-adherence.

As stated above, this office had not been in operation before these maneuvers and no accepted doctrines, procedures or techniques had been established. It is believed that the adoption of the recommendations of the 3 G-3 Air duty officers submitting reports will be a basis for the establishment of procedures and techniques.

b. Statement as to whether or not problem served its purpose:

Problem did serve its purpose in that it provided a means to determine and to evaluate the misconceptions held prior to the beginning of the Exercise.

c. Statement as to whether or not full use was made of capabilities (specific emphasis on AGOS capabilities) but including those of other elements of which reporter has accurate knowledge:

It is not felt that full use of the capabilities of the persons operating in the capacity of the G-3 Air duty officer were made. Example: The duty officer was not allowed to use plain common sense as regards mission requests. Two or more requests that obviously

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should be consolidated into one mission first had to be submitted, entered in the journal and completely processed. They were later disapproved by the Combat operations officer as such and came back with the suggestion that the be consolidated into one mission. The reporter has no accurate knowledge of the capabilities of the other sections within AGOS or of other elements.

d. General Conclusions

It is felt that those in AGOS should have more information on the capabilities, functions, Armor and ordnance of aircraft used by the Tactical Air Command; That all those within AGOS should be able to serve in a minor advisory capacity or at least be able to express an opinion to other army personnel on the proper type of aircraft to be used for a specific target.

5. Recommendations

a. Equipment:

It is recommended that the G-3 situation Map be placed directly in front of the Duty officer and that in addition to his regular telephone instruments he be given a head set ~~earphones~~ that can be plugged in to any of the Three circuits available. This will enable him to check The bomb safety line at the time a mission request is received, to plot targets as they come in and give him complete freedom of both hands

b. Communications:

Circuits provided were ideal except they did not work. Alternate means of communications must be provided.

c. Coordination:

No recommendations.

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d. Techniques & Procedures

1. All Units submitting mission requests be familiar with the operation of AGOS within J.O.C. and if the requesting Unit must have numbers for each request it is recommended that that number be assigned by the duty officer.

2. That one copy of the submitted requests be retained by the duty officer until the completed copy is returned by the Combat Operations Officer. This will enable the duty officer to check on the progress of requested missions.

e. Personnel and Administration:

Subordinates should take or be given instructions from one person only. This procedure will eliminate much of the confusion that was so much in evidence during this exercise.

f. Other:

No recommendation

Joseph H. Sears
Joseph H. Sears
1st Lt FA
G-3 Air Duty Officer

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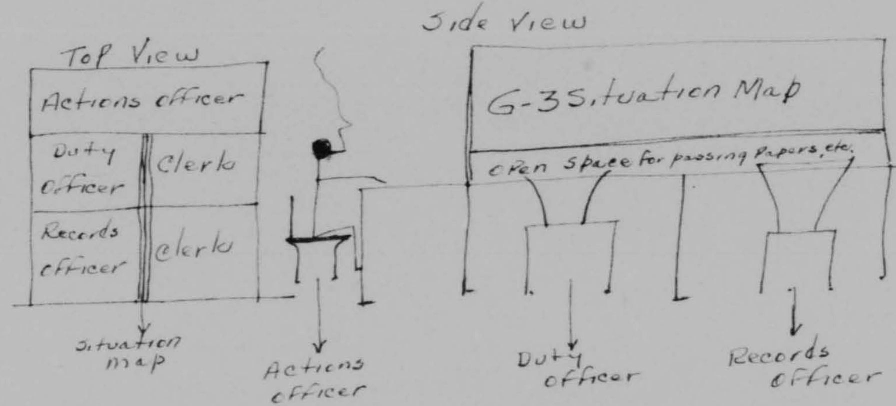
ANNEX "A"



Mission request is received by duty officer, checked on map infront of him, request form accomplished, passed to clerk for entry in journal and number, back to duty officer. and Then to actions officer. If discussion is necessary between actions and duty officers it can be accomplished without either moving or undue noise. Actions officer hands or takes request to COS - depending where the COS has his desk - and when mission is completed the actions officer passes completed form to duty officer who in turn gives it to records officer.

The G-2 Air is as should be entirely out of this picture. It might be placed in line after the records officer or anywhere G-2 desires

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FINAL REPORT OF GROUND UMPIRE

JOINT OPERATIONS CENTER, EXERCISE SWARMER

I. PROBLEM:

The Joint Operations Center was to accomplish unity between the Ground Troops and the Tactical Air Force in providing close support to the Ground troops; also assist in porviding aerial photographs of the terrain involved. Further mission was to evaluate the methods of close support and determine the requirements for supplying assault troops through and airhead established shortly after the assault.

II. SUMMARY OF EVENTS:

Joint Operations Center opened at Outer Camp Mackall on 14 Apr 50 with minimun confusion. However the actual operation did not begin until 17 Apr 50. At this time and through 22 Apr 50 the requests which were processed were of the aerial photo type. Most all these were flown by TAF. However most of the unit commanders were requesting the 1:4500 and 1:5000 basis. Due to the type A/C used, the timing and focal length of the camera it was impossible to obtain good photographs. So all of the missions laid on were on a 1:7000 basis and with excellent results.

During the week I acted as an observer, but on one day I acted as G-3 Air Actions Officer. This gave me an opportunity to observe the type requests the units were submitting. It was noted that some of the unit commanders were requesting the same photographic mission two days in a row. This would tax the availability of A/C and the production of the topographic company. It would not seem to be practical at this time as it is too far ahead of D-Day. However it would be sound policy when D-Day nears as the enemy situation would readily change and this would show up on the photographs.

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During the following week I had a chance to work in the capacity of G-3 Duty Officer. This gave me a chance to write the requests from the units and also had a better chance to evaluate the type request submitted. Most of the requests submitted were of enemy installations. However some of the requests were for pre-planned missions on transitory targets for the following day. This is not sound policy and they should have asked for On Call Missions. Normally a target of this type will not be in the same area two days in a row.

On D-Day I visited the initial drop on Rhine-Luzon DZ. The drop was to be made at 0630 hours but was cancelled until 0930 due to the A/C being weathered in. It was noted that a slight confusion existed in the reorganizing of the troops for the attack. In fact some units were not completely organized until about one hour after the drop. After the attack began I made a tour of the battalions and found that some of the FAC did not have contact with the A/C orbiting in the area. In one instance one battalion did not ever get his set into operation all during thier attack on Camp Mackall Air Field. This was a time that they needed it badly too. There was a radar station on the field which needed attacking before the troops could advance. On the other hand one battalion used the A/C to a good advantage in attacking a bridge which was held by the enemy. This bridge was important as it lead to the causeways. The A/C made at least three attacks on the bridge dispersing the enemy troops so that the US forces could advance.

D-Day afternoon I visited the drop of the 505 AIR on Holland DZ.

This drop was somewhat better organized than the initial drop due to the fact that the 505 had the support of the B-45 bomber and the F-84 fighters. In and during this drop the commanders made full use of the orbiting A/C and from information obtained from the recce A/C. One particular instance noted was that a truck column was coming up with troops to assist in repelling the airborne assault and an immeediate air strike was ordered on them.

On D+ 2 I again acted as G-3 Air Actions Officer and this gave me anotther opportunity to observe the type requests the units were sending in. In most cases the requests were of the armed recce type and only a few pre-planned missions. Most of the armed recce were aginst enemy troopsconcentrations and movemnets along the main supply routes. It was also noted that a few most requests were being sent in for pre-planning on transitory targets. At this time they should have asked for more ON CALL missions on these targets.

III. DISCUSSION:

One of the major problems of JOC was the manner in which the requests were received from the units. Most of this was due to the lines of communication which had partial failure. This solved sometime later when the lines cleared up.

Another major problem was the handling of Spot Reports from Recce A/C. In the earlier stages the G-3 Air Actions Officer did not have a chance to look at the reports and make a decision as to what should be done about the target reported. This was solved later by additional copies of the spot report being made and handled through the G-3 Air Action Officer. Then the units were notified as to the decision made and if an air strike was made or if it would be referred to tthe unit for laying artillery fire on it. In some

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cases the targets were behind the BSL and air strikes could not be laid on. The system of handling spot reports was devised by the Senior G-3 Air Actions Officer and the Senior Operations Officer.

Only one other major problem confronted JOC and that was the lines of communication to the GLO's and the units involved. It was very hard at times to get through to the proper persons and this was never solved completely.

IV. CONCLUSION:

On the whole JOC did accomplish its mission very well and found that high speed A/C could support ground troops closely. It was further found that it is possible to suppy and airborne assault in an air head close to the front lines, provided air superiorty could be maintained.

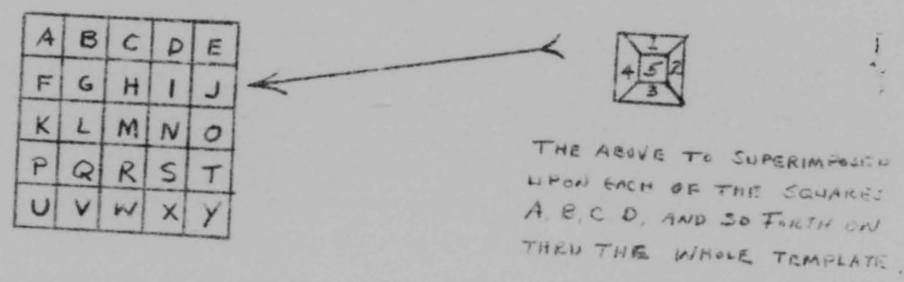
V. RECOMMENDATIONS:

It is recommended that the G-s Air Records Officer and the G-3 Duty Clerk on the third shift compile all the days reports and place them in the journal. The would give the G-3 Air Duty Officer and the G-3 Air Records Officer more time to spend in processing the requests from units and keeping them posted as to the disposition of each request and reasons if it were disapproved or if it were being laid on and at what time.

Further recommend that the attached diagram be adopted for future use in JOC. Sincerely believe that with this arrangement there would be less confusiOn in the center aisle and along the maps and boards on the wall. It will also tend to bring about closer coordination between the Ground and Air Force personnel.

Also recommend that JOC be made a definite part of all future operations.

Recommend that the following Target Area Designator System be considered for future uses. This would work very nicely on 1:25,000 map but could not be used very well on a 1:50,000 map.



Believe that the 62nd Topographic Company be given due credit for the fine and untiring work they did during the Exercise. They operated at full capcaity all time and never once did they say that they could not supply units with photographs requested.

Edward W. Gee
EDWARD W. GEE
Capt., Inf.
Ground Umpire

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FINAL REPORT OF GROUND UMPIRE

JOINT OPERATIONS CENTER, EXERCISE SWARMER

I. PROBLEM:

The Joint Operations Center was to accomplish unity between the Ground Troops and the Tactical Air Force in providing close support to the Ground troops; also assist in porviding aerial photographs of the terrain involved. Further mission was to evaluate the methods of close support and determine the requirements for supplying assault troops through and airhead established shortly after the assault.

II. SUMMARY OF EVENTS:

Joint Operations Center opened at Outer Camp Mackall on 14 Apr 50 with minimun confusion. However the actual operation did not begin until 17 Apr 50. At this time and through 22 Apr 50 the requests which were processed were of the aerial photo type. Most all these were flown by TAF. However most of the unit commanders were requesting the 1:4500 and 1:5000 basis. Due to the type A/C used, the timing and focal length of the camera it was impossible to obtain good photographs. So all of the missions laid on were on a 1:7000 basis and with excellent results.

During the week I acted as an observer, but on one day I acted as G-3 Air Actions Officer. This gave me an opportunity to observe the type requests the units were submitting. It was noted that some of the unit commanders were requesting the same photographic mission two days in a row. This would tax the availability of A/C and the production of the topographic company. It would not seem to be practical at this time as it is too far ahead of D-Day. However it would be sound policy when D-Day nears as the enemy situation would readily change and this would show up on the photographs.

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During the following week I had a chance to work in the capacity of G-3 Duty Officer. This gave me a chance to write the requests from the units and also had a better chance to evaluate the type request submitted. Most of the requests submitted were of enemy installations. However some of the requests were for pre-planned missions on transitory targets for the following day. This is not sound policy and they should have asked for On Call Missions. Normally a target of this type will not be in the same area two days in a row.

On D-Day I visited the initial drop on Rhine-Luzon DZ. The drop was to be made at 0630 hours but was cancelled until 0930 due to the A/C being weathered in. It was noted that a slight confusion existed in the reorganizing of the troops for the attack. In fact some units were not completely organized until about one hour after the drop. After the attack began I made a tour of the battalions and found that some of the FAC did not have contact with the A/C orbiting in the area. In one instance one battalion did not ever get his set into operation all during thier attack on Camp Mackall Air Field. This was a time that they needed it badly too. There was a radar station on the field which needed attacking before the troops could advance. On the other hand one battalion used the A/C to a good advantage in attacking a bridge which was held by the enemy. This bridge was important as it lead to the causeways. The A/C made at least three attacks on the bridge dispersing the enemy troops so that the US forces could advance.

D-Day afternoon I visited the drop of the 505 AIR on Holland DZ.

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This drop was somewhat better organized than the initial drop due to the fact that the 505 had the support of the B-45 bomber and the F-84 fighters. In and during this drop the commanders made full use of the orbiting A/C and from information obtained from the recce A/C. One particular instance noted was that a truck column was coming up with troops to assist in repelling the airborne assault and an immediate air strike was ordered on them.

On D/ 2 I again acted as G-3 Air Actions Officer and this gave me anotther opportunity to observe the type requests the units were sending in. In most cases the requests were of the armed recce type and only a few pre-planned missions. Most of the armed recce were aginst enemy troopsconcentrations and movemnets along the main supply routes. It was also noted that a few most requests were being sent in for pre-planning on transitory targets. At this time they should have asked for more ON CALL missions on these targets.

III. DISCUSSION:

One of the major problems of JOC was the manner in which the requests were received from the units. Most of this was due to the lines of communication which had partial failure. This solved sometime later when the lines cleared up.

Another major problem was the handling of Spot Reports from Recce A/C. In the earlier stages the G-3 Air Actions Officer did not have a chance to look at the reports and make a decision as to what should be done about the target reported. This was solved later by additional copies of the spot report being made and handled through the G-3 Air Action Officer. Then the units were notified as to the decision made and if an air strike was made or if it would be referred to tthe unit for laying artillery fire on it. In some cases the targets were behind the BSL and air strikes could not be laid on. The system of handling spot reports was devised by the Senior G-3 Air Actions Officer and the Senior Operations Officer.

Only one other major problem confronted JOC and that was the lines of communication to the GLO's and the units involved. It was very hard at times to get through to the proper persons and this was never solved completely.

IV. CONCLUSION:

On the whole JOC did accomplish its mission very well and found that high speed A/C could support ground troops closely. It was further found that it is possible to suppy and airborne assault in an air head close to the front lines, provided air superiorty could be maintained.

V. RECOMMENDATIONS:

It is recommended that the G-s Air Records Officer and the G-3 Duty Clerk on the third shift compile all the days reports and place them in the journal. The would give the G-3 Air Duty Officer and the G-3 Air Records Officer more time to spend in processing the requests from units and keeping them posted as to the disposition of each request and reasons if it were disapproved or if it were being laid on and at what time.

Further recommend that the attached diagram be adopted for future use in JOC. Sincerely believe that with this arrangement there would be less confusion in the center aisle and along the maps and boards on the wall. It will also tend to bring about closer coordination between the Ground and Air Force personnel.

Also recommend that JOC be made a definite part of all future operations.

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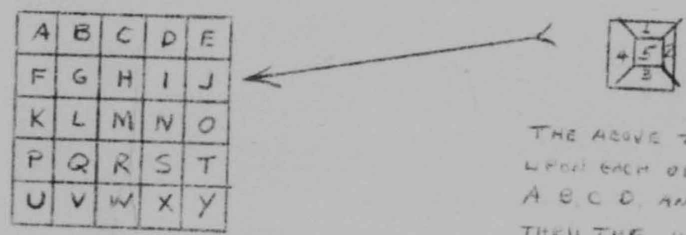
Reccommend that the following Target Area Designator System be considered for future uses. This would work very nicely on a 1:25,000 map but could not be too effective on a 1:50,000 map.



THE ABOVE TO SUPERIMPOSED UPON EACH OF THE SQUARES A B C D, AND SO FORTH ON THRU THE WHOLE TEMPLATE.

Belive that the 62nd Topographic Company be given due credit for the fine and untiring work they did during the Exercise. They operated at full capacity all time and never once did they say that they could not supply units with photographs requested.

Edward W. Gee
EDWARD W. GEE
Capt., Inf.
Ground Umpire

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Inclosure 2 ~~TAB "~~ to ACOS REPORT for EXERCISE SWARMER.

COMPILATION OF REPORTS OF GROUND LIAISON OFFICERS

1. GENERAL

Experience of Ground Liaison Officers employed during Exercise SWARMER developed the following as broad general functions of a Ground Liaison Officer:

a. Advising Air Force Units regarding:

(1) Friendly and enemy front lines.

(2) Position and characteristics of Bomb Safety Lines

(3) Enemy gro nd situation and friendly ground operations.

(4) Target locations, characteristics and peculiarities.

b. Briefing pilots before each mission, interrogating them after each mission and passing to JOC any information of value so obtained.

c. Assisting Operations Officer in preparation of Flash reports.

d. Orienting Air Force personnel on Air Ground Operations and procedures for securing and coordinating close air support.

e. Maintaining appropriate situation and operations maps.

f. Supervising his Air Ground Liaison Signal Team.

g. Acting upon all requests and orders from JOC.

h. Doing anything within his capabilities which will result in the most effective close air support for the Army unit he represents. He is usually the only Army Officer on duty with his Air Force unit; he will be expected to answer a multitude of questions concerning the ground operation and should prepare himself accordingly.

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2. SUMMARY OF EVENTS

Various GLO's found that their activities differed in details, but the general pattern was as follows:

a. Reported to JOC for duty o/a 3 April 1950 and attended a course of instruction in air ground operations during period 5-14 April.

b. Reported to Air Force unit with which affiliated on 15 April; secured quarters and arranged messing for themselves and their signal teams.

c. Introduced themselves to the Air Force Commanders and Staffs; explained their mission.

d. Supervised arrangements for their signal teams; arranged for remoting radio-telephone into Air Force Operations room where indicated.

e. Conducted a course of instruction for Air Force personnel, covering generally:

(1) V Corps plan of operations.

(2) Background of AGGRESSOR and the enemy activities to date.

(3) Air Ground Operations System procedures; tracing a request for air support from the infantry battalion through all channels to the completion of the mission, including the reports rendered thereon; emphasis placed on procedures to be employed in the early phases of the Airborne operation.

(4) Duties and functions of Ground Liaison Officers.

(5) Organization of Army units participating in SWARMER.

f. Set up situation and operation maps.

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g. Briefed and interrogated pilots on missions; reported necessary information to JOC.

h. Rendered all possible assistance to affiliated unit; helped secure maps and helped to smooth out operational procedures by reporting difficulties to AGOS/JOC; was available for duty as necessary at all hours, day or night.

i. Upon notification, shortly after 1000 hours, 3 May, that Exercise SWARMER was concluded, GLO's reported their observations to Air Force unit commanders and returned to Fort Bragg; rendered final individual reports on their operations and were released.

3. DISCUSSION

Concensus of Ground Liaison Officers indicates that their greatest problems were:

a. Communications

(1) A common complaint was the prolonged delay experienced in receiving information; GLO's reported a time lag up to three (3) days for delivery of coded messages. This delay, coupled with garbled transmissions, rendered practically useless any JOC efforts to keep GLO's properly advised. Similar difficulties on clear messages atrophied exchange of battle information between GLO' and JOC.

b. Inadequate Prior Preparation.

(1) The majority of Officers detailed to augment the permanent AGOS had little or no background in liaison work in air-ground operations, or in Air Force functions. In general, the more promising officers were assigned to ground liaison duties. Effective instruction was hampered by late reporting of augmentation officers, by other commitments of permanent AGOS personnel, by the magnitude of the task and, additionally, for GLO's by a basic lack of available study material. GLO's were consequently prepared for their duties to a lesser

degree than was desirable. By assiduous individual application, they happily overcame this initial deficiency; however, air-ground operations will be better served in the future if GLO's can be more thoroughly oriented on their duties before reporting to their affiliated units.

c. Insufficient Personnel

(1) GLO's were on duty over protracted periods. Passage of information from JOC after the evening planning conference required that GLO's function late at night, assimilating and posting intelligence and operational information. Often, pre-dawn briefing of pilots was required. Operations throughout the day required GLO presence. A qualified operations non-commissioned officer to handle routine matters would have materally reduced the load on the GLO and rendered his operations more effective.

4. CONCLUSIONS

a. Ground Liaison Officers adhered to accepted doctrine in performance of their duties; they constituted an essential element in the successful operation of the air-ground system.

b. Communications provided by the Signal Air-Ground Liaison Company were inadequate because they failed to handle the required traffic expeditiously, accurately and without interruptions.

c. The pre-operation training program conducted by permanent AGOS officers was adequate, but a more through course of

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instruction and the provision of more complete supply kits would have made Ground Liaison Officer operations easier and more effective.

5. RECOMMENDATIONS

a. That Ground Liaison Officers be provided with direct teletype communication (radio or land line) with JOC; that rapid encoding equipment, preferably integrated with teletype, be provided; that improved voice communication facilites be provided between GLO's and JOC; such voice facilities should permit rapid contact and break-in conversation.

b. That orientation and instructional material for Ground Liaison Officers be prepared and assembled; that Ground Liaison Officer kits, containing equipment and supplies peculiar to the needs of liaison teams be developed and made available to such teams in the future.

c. That Ground Liaison Officer teams be augmented by a minimum of one (1) Liaison non-commissioned officer SSN 2705 or equivalent.

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JOINT OPERATIONS CENTER
AIR-GROUND OPERATIONS SECTION
POST EXERCISE REPORT-EXERCISE SWARMER

1. STATEMENT AND PURPOSE OF PROBLEM:

G-3 Air Duty Officer on first shift from 0500 to 1300 daily. Charged with receiving and processing mission requests other than reconnaissance, from Corps and Divisions, keeping Ground Liaison Officers, Corps and Divisions informed as to location and changes of the bomb safty line and maintaining the friendly situation on the ground situation map.

2. SUMMARY OF EVENTS:

a. General description of routine operations.

Received all requests for air support other than reconnaissance. These requests were recorded on a special mimographed mission request form in four (4) copies. Upon reciept of a mission request, target was plotted on the ground situation map. The journal entry number of th t request was also recorded on the map. This t rget was then checked in its relation to the front lines and the bomb safty line. The mission request was then submitted to the G-3 Air Actions Officer's hands, the G-3 Air Duty Officer was free to return to his desk and recieve other missions. Kept all Ground Liaison Officers, V Corps, and Divisions informed as to the location of the bomb safty line and any changes that occurred in its loc tion.

Maintained the friendly situation on the ground situation map at all times.

In addition to the above, the G-3 Air Duty Officer and the G-3 Air Records Officer, coordinated their effort in keeping a day to day journal on all mission requests, messages, and other events.

b. Description of unusual operations, problems or equipment:

One of the main difficulties encountered was the failure of COS to promptly return a copy of the mission request to AGOS. Missions which were

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allotted to air alert aircraft sometimes were never returned until a search was made to locate them in order to close out the journal. It was observed that "On Call" mission requests were returned much faster than "Preplanned" mission requests. TACC was very slow in returning the circulating copy of the mission request which gave information as to the results of the mission. It was noted that there was improvement in this though, as the exercise progressed. Failure of COS to return our copy of the requests promptly, left our records incomplete. Because of this we were unable to keep requesting units posted on the status of their mission requests.

Another problem was having clerks assigned to a shift who were unable to type. Every clerk in the Joint Operations Center should be a typist due to the large volume of reports.

Lack of good, reliable communications hindered the performance of our mission. The basic plan of communications seems sound. That is having radio remoted to the G-3 Air Duty Officer with a Ground Liaison Officers net and a G-3 requests net. During the exercise these nets were always overloaded and most messages had to be sent C.W. with an operational priority. It seems that everyone was using an operational priority though because before the end of the exercise this priority did not mean much as far as getting a message through faster was concerned.

Several messages of an administrative nature were filed in the G-3 air journal. I believe that this should not be done as it tends to make the journal more a scrapbook of routine information than a journal of accurate operational data for which it is intended.

3. DISCUSSION:

a. Opinion on facts:

In my opinion, the physical layout of the Joint Operations Center, as operated during exercise swarmer, is not the correct answer. Due to the congestion

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of the Joint Operations Center, it should be set up to avoid as much movement as possible in each person's performance of his mission. As presently set up, the G-3 Air Duty Officer after receiving a mission request, has to move completely around the room to get to the ground situation map. If he has to make notes while at the map, he must use someone else's desk to do so. If the G-3 Air Actions Officer has some information for the Duty Officer, he either has to shout for him to come to his desk, shout the information to him, or get up and go to his desk. If the Actions Officer wants information from the journal, he has to go through one of the above processes with the G-3 Air Clerk. This happens frequently and thereby adds to the confusion within the Joint Operations Center.

b. Description of newly proposed improvements (Improvement #1) (See inclosure #1 for proposed lay-out of JOC).

If the lay-out of the Joint Operations Center was se

inclosed sketch, the G-3

Officer for him to be able to converse w

normal tone of voice thereby saving noise and movement within the Joint Operations Center. In this set-up the G-3 Air Actions Officer and the Senior Operations Officer could see the ground situation map without moving from their position. Upon receiving a mission request, the G-3 Air Duty Officer would only have to turn around, plot the trget, and hand it to the G-3 Air Actions Officer without moving from his general area.

One argument which has been raised against this proposal is this: Th t the Ground Officer and his counter part in the Air Force should sit side by side. During Exercise Swarmer there was no indication that they should be seated in that manner. Since the G-3 Air Acti ns Officer submitted all requests to the C.O.S., the Ground, and Air Duty Officers had no occasion to consult each other.

(Improvement #2)

At the beginning of Exercise Swarmer there seemed to be some doubt as to

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who should keep a file on the spot reports since some pertained to Intelligence and some to operations. It was finally decided that G-2 Air would pass them to G-3 Air for information and to be returned for G-2 Air files.

See inclosure #2 for a proposed mimographed form to be used to record all spot reports of an operational nature. Recommend that these forms be kept by the Chief G-3 Air Clerk and be entered into the journal at the end of the day as one journal entry. This would give a complete record of targets hit by alert aircraft which would not otherwise appear in the journal.

4. CONCLUSIONS:

a. It seems that G-3 Air adhered to accepted doctrine procedures and techniques during the Exercise as nearly as possible. Some variation from the accepted Doctrine was caused by poor communications to Ground Liaison Officers and other units.

b. The problem served its purpose since it proved that the basic doctrine of Joint Operations was sound and it served to uncover a lot of small problems which can be corrected with a little effort.

c. Full use was made of all capabilities.

5. RECOMMENDATIONS:

a. Equipment.

Recommend that the M209 converter be replaced with some faster means of encoding and decoding messages.

b. Communications:

Recommend that a qualified Officer be appointed to make a study to determine where the trouble lies in the present communications set-up and make recommendations for improvement.

c. Coordination:

Recommend that at the beginning of a shift that the G-3 Air Actions Officer thoroughly brief the Duty and Records Officer on the situation and outline the plans that are going to be put into effect to the best of his knowledge. This would help these two Officers to better perform their mission.

d. Techniques and Procedure:

Negative except for plan outlined in (3) (b) above concerning spot reports.

e. Personnel and Administration:

Recommend that qualified typist be furnished as G-3 Clerks.

Recommend that a small hut be furnished for administration and preparation of reports.

JAMES E. REEVES
1st Lt. F.A.
G-3 Air Duty Officer

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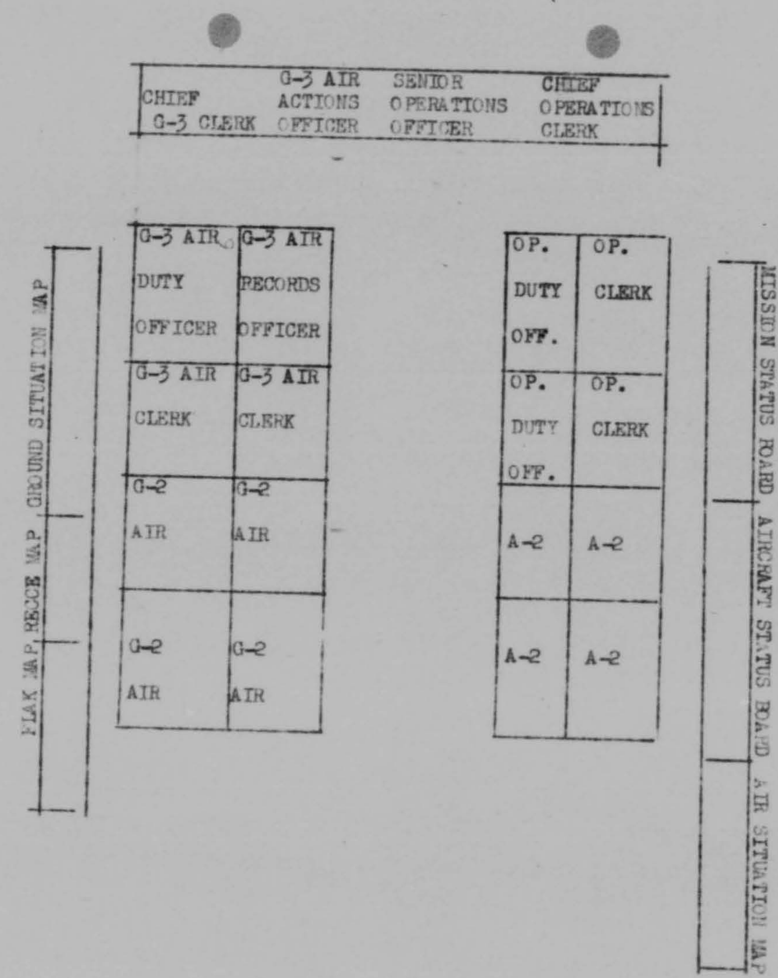

INCLOSURE # 1.

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RECORD OF SPOT REPORTS

FOR G-3 AIR (PERIOD _____ TO _____

Celery 104 — Identification

27 0900 R — Time Rec'd by G-3 Air

Text of Report ______________________________

Action Taken ______________________________

Identification ______________

Time Rec'd by G-3 Air ______________

Text of Report ______________________________

Action Taken ______________________________

Identification ______________

Time Rec'd by G-3 Air ______________

Text of Report ______________________________

Action Taken ______________________________

INCLOSURE #2

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JOINT OPERATIONS CENTER
AIR-GROUND OPERATIONS SECTION
POST EXERCISE REPORT-EXERCISE SWARMER

1. STATEMENT AND PURPOSE OF PROBLEM:

G-3 Air Duty Officer on first shift from 0500 to 1300 daily. Charged with receiving and processing mission requests other than reconnaissance, from Corps and Divisions, keeping Ground Liaison Officers, Corps and Divisions informed as to location and changes of the bomb safty line and maintaining the friendly situation on the ground situation map.

2. SUMMARY OF EVENTS:

a. General description of routine operations.

Received all requests for air support other than reconnaissance. These requests were recorded on a special mimographed mission request form in four (4) copies. Upon reciept of a mission request, target was plotted on the ground situation map. The journal entry number of that request was also recorded on the map. This target was then checked in its relation to the front lines and the bomb safty line. The mission request was then submitted to the G-3 Air Actions Officer's hands, the G-3 Air Duty Officer was free to return to his desk and recieve other missions. Kept all Ground Liaison Officers, V Corps, and Divisions informed as to the location of the bomb safty line and any changes that occurred in its location.

Maintained the friendly situation on the ground situation map at all times.

In addition to the above, the G-3 Air Duty Officer and the G-3 Air Records Officer, coordinated their effort in keeping a day to day journal on all mission requests, messages, and other events.

b. Description of unusual operations, problems or equipment:

One of the main difficulties encountered was the failure of COS to promptly return a copy of the mission request to AGOS. Missions which were

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allotted to air alert aircraft sometimes were never returned until a search was made to locate them in order to close out the journal. It was observed that "On Call" mission requests were returned much faster than "Preplanned" mission requests. TACC was very slow in returning the circulating copy of the mission request which gave information as to the results of the mission. It was noted that there was improvement in this though, as the exercise progressed. Failure of COS to return our copy of the requests promptly, left our records incomplete. Because of this we were unable to keep requesting units posted on the status of their mission requests.

Another problem was having clerks assigned to a shift who were unable to type. Every clerk in the Joint Operations Center should be a typist due to the large volume of reports.

Lack of good, reliable communications hindered the performance of our mission. The basic plan of communications seems sound. That is having radio remoted to the G-3 Air Duty Officer with a Ground Liaison Officers net and a G-3 requests net. During the exercise these nets were always overloaded and most messages had to be sent C.W. with an operational priority. It seems that everyone was using an operational priority though because before the end of the exercise this priority did not mean much as far as getting a message through faster was concerned.

Several messages of an administrative nature were filed in the G-3 air journal. I believe that this should not be done as it tends to make the journal more a scrapbook of routine information than a journal of accurate operational data for which it is intended.

3. DISCUSSION:

a. Opinion on facts:

In my opinion, the physical layout of the Joint Operations Center, as operated during exercise swarmer, is not the correct answer. Due to the congestion

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of the Joint Operations Center, it should be set up to avoid as much movement as possible in each person's performance of his mission. As presently set up, the G-3 Air Duty Officer after receiving a mission request, has to move completely around the room to get to the ground situation map. If he has to make notes while at the map, he must use someone else's desk to do so. If the G-3 Air Actions Officer has some information for the Duty Officer, he either has to shout for him to come to his desk, shout the information to him, or get up and go to his desk. If the Actions Officer wants information from the journal, he has to go through one of the above processes with the G-3 Air Clerk. This happens frequently and thereby adds to the confusion within the Joint Operations Center.

b. Description of newly proposed improvements (Improvement #1) (See inclosure #1 for proposed lay-out of JOC).

If the lay-out of the Joint Operations Center was set up as proposed in the inclosed sketch, the G-3 Air Section would be near enough to the G-3 Air Actions Officer for him to be able to converse with any member of the section in a normal tone of voice thereby saving noise and movement within the Joint Operations Center. In this set-up the G-3 Air Actions Officer and the Senior Operations Officer could see the ground situation map without moving from their position. Upon receiving a mission request, the G-3 Air Duty Officer would only have to turn around, plot the trget, and hand it to the G-3 Air Actions Officer without moving from his general area.

One argument which has been raised against this proposal is this: That the Ground Officer and his counter part in the Air Force should sit side by side. During Exercise Swarmer there was no indication that they should be seated in that manner. Since the G-3 Air Actions Officer submitted all requests to the C.O.S., the Ground, and Air Duty Officers had no occasion to consult each other.

(Improvement #2)

At the beginning of Exercise Swarmer there seemed to be some doubt as to

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who should keep a file on the spot reports since some pertained to Intelligence and some to operations. It was finally decided that G-2 Air would pass them to G-3 Air for information and to be returned for G-2 Air files.

See inclosure #2 for a proposed mimographed form to be used to record all spot reports of an operational nature. Recommend that these forms be kept by the Chief G-3 Air Clerk and be entered into the journal at the end of the day as one journal entry. This would give a complete record of targets hit by alert aircraft which would not otherwise appear in the journal.

4. CONCLUSIONS:

a. It seems that G-3 Air adhered to accepted doctrine procedures and techniques during the Exercise as nearly as possible. Some variation from the accepted Doctrine was caused by poor communications to Ground Liaison Officers and other units.

b. The problem served its purpose since it proved that the basic doctrine of Joint Operations was sound and it served to uncover a lot of small problems which can be corrected with a little effort.

c. Full use was made of all capabilities.

5. RECOMMENDATIONS:

a. Equipment.

Recommend that the M209 converter be replaced with some faster means of encoding and decoding messages.

b. Communications:

Recommend that a qualified Officer be appointed to make a study to determine where the trouble lies in the present communications set-up and make recommendations for improvement.

c. Coordination:

Recommend that at the beginning of a shift that the G-3 Air Actions Officer thoroughly brief the Duty and Records Officer on the situation and outline the plans that are going to be put into effect to the best of his knowledge. This would help these two Officers to better perform their mission.

d. Techniques and Procedure:

Negative except for plan outlined in (3) (b) above concerning spot reports.

e. Personnel and Administration:

Recommend that qualified typist be furnished as G-3 Clerks.

Recommend that a small hut be furnished for administration and preparation of reports.

JAMES E. REEVES
1st Lt. F.A.
G-3 Air Duty Officer

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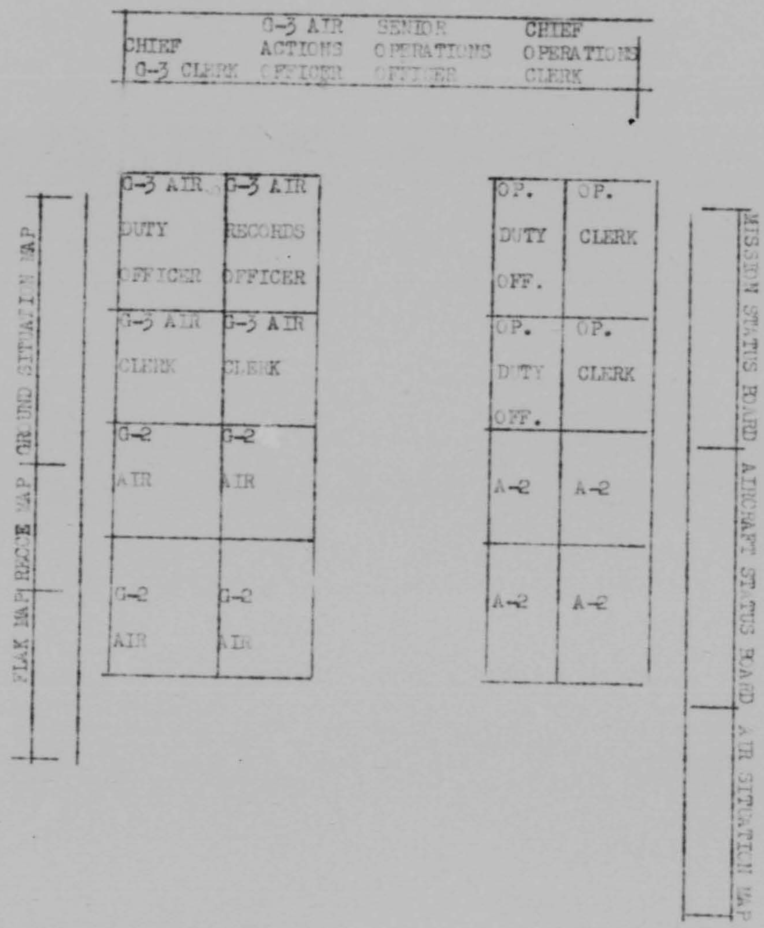

INCLOSURE # 1.

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RECORD OF SPOT REPORTS

FOR G-3 AIR (PERIOD _____ TO _____

Celery 104 — Identification

27 0900 R — Time Rec'd by G-3 Air

Text of Report ______________________________

Action Taken ______________________________

______ Identification

______ Time Rec'd by G-3 Air

Text of Report ______________________________

Action Taken ______________________________

______ Identification

______ Time Rec'd by G-3 Air

Text of Report ______________________________

Action Taken ______________________________

INCLOSURE #2

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File

JOINT OPERATIONS CENTER
AIR-GROUND OPERATIONS SECTION
POST EXERCISE REPORT-EXERCISE SWARMER

I. The problem consisted of operating as a G-3 Action Officer in the AGOS of of the JOC of a Tactical Air Force operating with an Airborne Corps in a totally Airborne operation. The purpose of the problem was to test:

a. The feasibility of operating the JOC of a Tactical Air Force at Corps level with the Tactical Air Force used principally in direct support of the Ground Forces.

b. The procedures set forth in the present doctrine established for an operating JOC.

c. The communications feasibilities presently available to JOC.

d. Liaison between Ground Force and Air Force.

e. The practicability of the present manning level of JOC.

f. The practicability of present administrative functions of the JOC as established by the doctrine.

II. Summary of Events

a. Order of events

(1) Instruction was received in JOC doctrine, duties of AGOS personnel, communications facilities of AGOS, coordination with AFOS, processing of pre-arranged and on call missions, and physical set up of JOC.

(2) Move to field with TAF.

(3) Planning stage operations of AGOS in period prior to an air assault.

(4) Operation of AGOS during air assault of Airborne Corps.

(5) Operation of AGOS during ground operations.

(6) End of Maneuver.

b. Routine operations of the G-3 Air Action Officer consisted of supervision of the preparation of the daily summary report after 2400 for the days events; checking the Air Force Operations order to insure that preplanned

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missions were included in the order and were corect; processing of mission requests received too late to be included in the Air Force operations order, and coordinating with the air operations Officer in having these requests flown; and, through cooporation with the air operations Officer, making decisions on cancellation of certain targets, when weather conditions or enemy action reduced the available air effort so as to interfere with preplanned missions.

During daylight hours the Action Officer processed on call requests for missions to be flown in direct support of ground forces; coordinated with the operations Officer on targets to be hit by alert aircraft, on call aircraft, or diversion of aircraft to more important targets; received spot reports and determined wether the target should be hit immediately with available aircraft or available Artillery, and took appropriate action; referred intelligence information to the G-2 Air section; supervised forwarding of information to requesting agencies concerning requests for air support; supervised posting of front lines, boundaries, bomb safety lines, and targets on operations map; Attended evening planning conference; made recommendations to G-3 air concerning preplanned missions, allocation of air effor for the following days operations, and bomb safety lines; and, supervised the maintenance of the journal:

c. Unusual operations, problems, or equipment:

Due to the type of operation conducted, many problems arose that may usually occur, first: in a totally Airborne operation less Artillery was available for support than the Infantry normally expects. Consequently, the Air Force assumed the role of direct support Artillery instead of its normal role of Army Artillery. Perticularly in the early phases of the operation. Missions were flown on targets that would normally have been attacked by Corps or Division Artillery, and in some instances by mortars or recoilless weapons.

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Second: The JOC did not accompany the Corps on the air landing, which may or may not be normal in a similar combat operation, consequently the lines of communications between JOC, Corps Headquarters, and Divisions became considerably extended, and caused communications difficulties in the operation.

Third: Communications difficulties were experienced in the employment of the 20 to ACL. In sufficiently trained personnel and antignated equipment could not support the communications load of the operation. Perticular difficulty was experienced in the use of the M-209 converter for encoding and decoding messages.

Fourth: No Corps FSCC was employed in the operation which resulted in the by passing of this important part of the AGOS System.

3. a. Opinions of the reporter on facts:

(1) The personnel attached to AGOS for Exercise SWARMER were insufficiently trained in the details of their respective duties in the operation of the AGOS prior to the Maneuver.

(2) There was a lack of cooperation and coordination between the sections of the AGOS and between the AGOS and the AFOS.

(3) Communications facilities were inadegnate for the efficient operation of the AGOS.

(4) A detailed operating procedure for handling the various missions and administrative functions of the AGOS was not established prior to the operation.

b. Opinions of other observers on the above facts were not recorded.

c. Description of newly proposed improvements.

(1) Use of a purely operations map for the purpose of plotting friendly front lines, boundries, bomb safety lines, objectives, and targets.

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map should be of a scale appropriate to the magnitude of the front to be covered during the operation. A map of a scale of 1/25,000 could be utilized in a localized situation such as Swarmer, maps of 1/50,000 or 1/100,000 should be used in operations covering large land masses or large zone of operations.

(2) Establishement of direct land lines to GHQ's, Corps, and Divisions. Duty Officer and Clerk equipped with headset and on a common simple switchboard into which direct lines are connected. Communications established with interested parties simply by making a connection.

(3) Minor rearrangement of AGOS (See annex #1)

CONCLUSIONS:

a. As far as can be determined there were no serious departures from the procedures and techniques laid down in the doctrine except as were dictated by necessity by scope of the problem. A TAF operating with a Corps instead of an Army is in itself a departure from the doctrine. Also because of the peculiarities of the specific problem TAF had more AF units assigned than is normal for operation with an army.

b. The problem did serve the purpose for which it was conducted in that it did prove: (1) the feasibility of a TAF operating with an Airborne Corps indirect support of Ground Forces in the role of Artillery. It proved that the AF could carry out this role successfully for a limited length of time in favorable weather.

(2) That the present procedures and techniques established by the doctrine are sound.

(3) Communications facilities available to JOC at present are inadequate.

(4) Liaison between AF and Ground Forces are established on a workable basis.

(5) That the present manning level of JOC is adequate.

(6) Established administrative functions of the JOC are practical.

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c. The full capabilities of the ACOS were not utilized as communications difficulties prevented the processing of on call missions in direct support of ground units. After the beginning of the Air assault there was no instance where a front line unit determined their need for air support, submitted the request through normal channels, and received the support in sufficient time to affect the immediate tactical situation of the requesting unit.

d. General Conclusions.

The ACOS operated successfully in the field under a given but unusual situation of a totally Airborne operation. Attached personnel were insufficiently trained in their duties prior to participation in the operation. Communications personnel were insufficiently trained and communications equipment was too antiquated to carry the communications load for the scope of this particular problem. Many of the difficulties that existed would have been overcome if the problem had continued.

4. RECOMMENDATIONS:

a. Equipment : Transportation for the ACOS become organic in the TAF, in order that maintenance can be performed without expanding the manning level of the ACOS.

b. Communications: That a system be devised for direct wire communications between ACOS, GLO's, and supported units. That better encoding and decoding devices be utilized in the ACOS system. That radio equipment be utilized that will insure radio communications between ACOS, GLO's, and supported units.

c. Coordination: That G-3 Air Action Officer be redesignated as Action Officer and be placed in charge of the operating personnel in the operating ACOS on his shift. That CPX's be conducted periodically by the entire system to include Division, and Corps FSCC and the JOC to promote coordination and cooperation.

d. Techniques and procedures: That the techniques and procedures be standardized and as far as possible itemized, to assist personnel in the performance of their duties.

e. Personnel and Administration: That the G-3 Section consist of a G-3 Actions Officer, a Duty Officer, one clerk and a typist on duty in the JOC with a records Officer and clerk at another location. That the G-2 section consist of a combat Intelligence Officer, and clerk in the JOC with other G-2 personnel at another location.

f. That complete lesson plans and training programs be prepared for future instruction of [illegible] personnel.

g. That operational personnel of the [illegible] be relieved of the maintenance of records for historical records, and that this duty be delegated to the most experienced Officer available. This system will allow the operating personnel to carry out their operational duties more efficiently. Also the experienced officer will be able to obtain better material for historical purposes and be able to view the operations objectively without becoming involved in the operations.

J. W. POWERS
Capt F.A.

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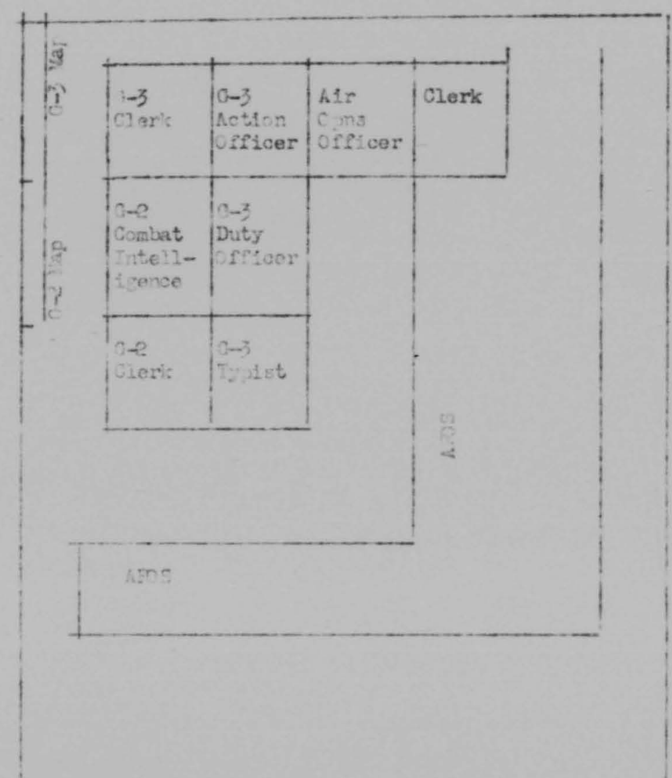
ANNEX #1



NOTE: G-3 Clerk maintains G-3 map under supervision of G-3 Duty Officer.

NOTE: Other G-3 and G-2 personnel who exist for the purpose of keeping records and for planning purposes, should not be physically in the operating JOC.

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JOINT OPERATIONS CENTER
AIR-GROUND OPERATIONS SECTION
POST EXERCISE REPORT-EXERCISE SWARMER

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b. The procedures set forth in the present doctrine established for an operating JOC.

c. The communications feasibilities presently available to JOC.

d. Liaison between Ground Force and Air Force.

e. The practicability of the present manning level of JOC.

f. The practicability of present administrative functions of the JOC as established by the doctrine.

II. Summary of Events

a. Order of events

(1) Instruction was received in JOC doctrine, duties of AGOS personnel, communications facilities of AGOS, coordination with AFOS, processing of pre-arranged and on call missions, and physical set up of JOC.

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(3) Planning stage operations of AGOS in period prior to an air assault.

(4) Operation of AGOS during air assault of Airborne Corps.

(5) Operation of AGOS during ground operations.

(6) End of Maneuver.

b. Routine operations of the G-3 Air Action Officer consisted of supervision of the preparation of the daily summary report after 2400 for the days events; checking the Air Force Operations order to insure that preplanned

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missions were included in the order and were corect; processing of mission requests received too late to be included in the Air Force operations order, and coordinating with the air operations Officer in having these requests flown; and, through cooporation with the air operations Officer, making decisions on cancellation of certain targets, when weather conditions or enemy action reduced the available air effort so as to interfere with preplanned missions.

During daylight hours the Action Officer processed on call requests for missions to be flown in direct support of ground forces; coordinated with the operations Officer on targets to be hit by alert aircraft, on call aircraft, or diversion of aircraft to more important targets; received spot reports and determined wether the target should be hit immediately with available aircraft or available Artillery, and took appropriate action; referred intelligence information to the G-2 Air section; supervised forwarding of information to requesting agencies concerning requests for air support; supervised posting of front lines, boundaries, bomb safety lines, and targets on operations map; Attended evening planning conference; made recommendations to G-3 air concerning preplanned missions, allocation of air effor for the following days operations, and bomb safety lines; and, supervised the maintenance of the journal:

c. Unusual operations, problems, or equipment:

Due to the type of operation conducted, many problems arose that may usually occur, first: in a totally Airborne operation less Artillery was available for support than the Infantry normally expects. Consequently, the Air Force assumed the role of direct support Artillery instead of its normal role of Army Artillery. Perticularly in the early phases of the operation. Missions were flown on targets that would normally have been attacked by Corps or Division Artillery, and in some instances by mortars or recoilless weapons.

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Second: The JOC did not accompany the Corps on the air landing, which may or may not be normal in a similar combat operation, consequently the lines of communications between JOC, Corps Headquarters, and Divisions became considerably extended, and caused communications difficulties in the operation.

Third: Communications difficulties were experienced in the employment of the 20 to ACL. In sufficiently trained personnel and antignated equipment could not support the communications load of the operation. Perticular difficulty was experienced in the use of the M-209 converter for encoding and decoding messages.

Fourth: No Corps FSCC was employed in the operation which resulted in the by passing of this important part of the AGOS System.

3. a. Opinions of the reporter on facts:

(1) The personnel attached to AGOS for Exercise SWARMER were insufficiently trained in the details of their respective duties in the operation of the AGOS prior to the Maneuver.

(2) There was a lack of cooperation and coordination between the sections of the AGOS and between the AGOS and the AFOS.

(3) Communications facilities were inadegnate for the efficient operation of the AGOS.

(4) A detailed operating procedure for handling the various missions and administrative functions of the AGOS was not established prior to the operation.

b. Opinions of other observers on the above facts were not recorded.

c. Description of newly proposed improvements.

(1) Use of a purely operations map for the purpose of plotting friendly front lines, boundries, bomb safety lines, objectives, and targets.

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map should be of a scale appropriate to the magnitude of the front to be covered during the operation. A map of a scale of 1/25,000 could be utilized in a localized situation such as Swarmer, maps of 1/50,000 or 1/100,000 should be used in operations covering large land masses or large zone of operations.

(2) Establishement of direct land lines to GLO's, Corps, and Divisions. Duty Officer and Clerk equipped with headset and on a common simple switchboard into which direct lines are connected. Communications established with interested parties simply by making a connection.

(3) Minor rearrangement of AGOS (See annex #1)

CONCLUSIONS:

a. As far as can be determined there were no serious departures from the procedures and techniques laid down in the doctrine except as were dictated by necessity by scope of the problem. A TAF operating with a Corps instead of an Army is in itself a departure from the doctrine. Also because of the peculiarities of the specific problem TAF had more AF units assigned than is normal for operation with an army.

b. The problem did serve the purpose for which it was conducted in that it did prove: (1) the feasibility of a TAF operating with an Airborne Corps indirect support of Ground Forces in the role of Artillery. It proved that the AF could carry out this role successfully for a limited length of time in favorable weather.

(2) That the present procedures and techniques established by the doctrine are sound.

(3) Communications facilities available to JOC at present are inadequate.

(4) Liaison between AF and Ground Forces are established on a workable basis.

(5) That the present manning level of JOC is adequate.

(6) Established administrative functions of the JOC are practical.

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c. The full capabilities of the AGOS were not utilized as communications difficulties prevented the processing of on call missions in direct support of ground units. After the beginning of the Air assault there was no instance where a front line unit determined their need for air support, submitted the request through normal channels, and received the support in sufficient time to affect the immediate tactical situation of the requesting unit.

d. General Conclusions.

The AGOS operated successfully in the field under a given but unusual situation of a totally Airborne operation. Attached personnel were insufficiently trained in their duties prior to participation in the operation. Communications personnel were insufficiently trained and communications equipment was too antiquated to carry the communications load for the scope of this particular problem. Many of the difficulties that existed would have been overcome if the problem had continued.

4. RECOMMENDATIONS:

a. Equipment : Transportation for the AGOS become organic in the TAF, in order that maintenance can be performed without expanding the manning level of the AGOS.

b. Communications: That a system be devised for direct wire communications between AGOS, GLO's, and supported units. That better encoding and decoding devices be utilized in the AGOS system. That radio equipment be utilized that will insure radio communications between AGOS, GLO's, and supported units.

c. Coordination: That G-3 Air Action Officer be redesignated as Action Officer and be placed in charge of the operating personnel in the operating AGOS on his shift. That CPX's be conducted periodically by the entire system to include Division, and Corps FSCC and the JOC to promote

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coordination and cooperation.

d. Techniques and procedures: That the techniques and procedures be standardized and as far as possible itemized, to assist personnel in the performance of their duties.

e. Personnel and Administration: That the G-3 Section consist of a G-3 Actions Officer, a Duty Officer, one clerk and a typist on duty in the JOC with a records Officer and clerk at another location. That the G-2 section consist of a combat Intelligence Officer, and clerk in the JOC with other G-2 personnel at another location.

f. That complete lesson plans and training programs be prepared for future instruction of AGOS personnel.

g. That operational personnel of the AGOS be relieved of the maintenance of records for historical records, and that this duty be delegated to the most experienced Officer available. This system will allow the operating personnel to carry out their operational duties more efficiently. Also the experienced officer will be able to obtain better material for historical purposes and be able to view the operations objectively without becoming involved in the operations.

J. W. POWERS
Capt F.A.

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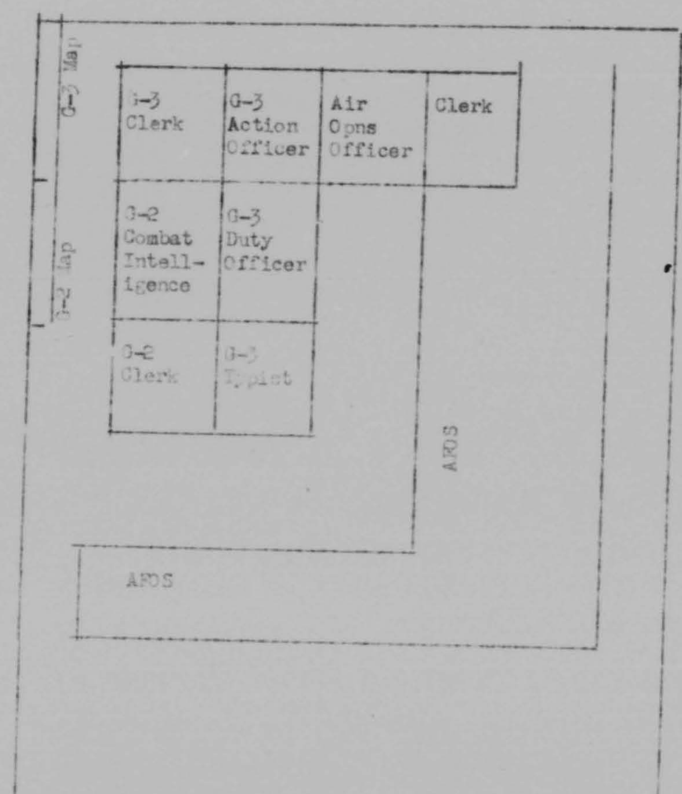
ANNEX #1



NOTE: G-3 Clerk maintains G-3 map under supervision of G-3 Duty Officer.

NOTE: Other G-3 and G-2 personnel who exist for the purpose of keeping records and for planning purposes, should not be physically in the operating JOC.

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AIR GROUND OPERATIONS SECTION

JOINT OPERATIONS CENTER

OPERATIONS

As Headquarters, Swarmer, was concerned over conflicts in AAA control measures prescribed in the Operational Plans of various participants in the Exercise, an AAA Control Conference was called at Swarmer Headquarters, J-3, to coordinate control measures. Such Control measures had already been coordinated between Headquarters, TAF, and and Headquarters, Carolina Base Section, Headquarters, V Corps. Representatives of all interested Headquarters attended and the principles agreed upon by Headquarters, V-Corps, Headquarters, TAF, and Headquarters, CBS, were embodied in the Operational Plans of other affected Headquarters.

Non-availability of airlift precluded the provision of a signal team from the 20th Signal Company Air Ground Liaison for utilization by 3rd Infantry Division (CBX BASES). As a result, it was necessary for the 3rd Infantry Division to process air support requests through V Corps, G-3 Air communications facilities.

In order to expedite submission and processing of air requests, maps of the area overprinted with the 1000 meter grid system utilized by between Air Force units were obtained with distribution to the participating combat ground force units down to and including parachute regimental commanders. As a result the Forward Air Controller and the Ground Force Commanders mentioned above were able to operate from the same type map.

Requirements arose from ground liaison officers and signal teams operating with Air National Guard units for gasoline and similar type

~~services.~~ ~~This was arranged for~~ The necessary coordination was effected through the interested special staff sections. In order to brief all interested air personnel on plans requirements for ~~D-Day~~, a Joint Operations Center briefing team was sent to each of the airfields; Oceana NAS, Va., Langley AFB, Va., Shaw AFB, S.C., Congaree AB, S.C., Morris Field, Charlotte, N.C. Detailed plans, methods of aircraft control, target marking and processing of requests for air support were discussed by representatives of the Air Ground Operations Section and the Combat Operations Section.

The necessity for close coordination of flights of liaison type aircraft was emphasized in the operation. Arrangements were made to coordinate such flights through the Fire Support Coordination Center. As requests for air support passed through this center, it was possible to work out the details of coordination efficiently.

For the purpose of testing ~~the~~ air ~~ground~~ support communications ~~system~~, an Air Ground Communications Exercise was conducted prior to D Day with the participating combat units. During the morning hours, experience was gained in processing requests for air missions within the divisions utilizing aircraft on air alert. Forward Air Controllers with Parachute Infantry Battalions and Regiments actually controlled the aircraft in flight. During the afternoon, requests were submitted for air support by the divisions to the Joint Operations Center utilizing the air ground communications system. Requests were processed in the usual manner and missions flown by the Air Force.

Final coordination of air support requirements for D ~~minus~~-1 and D-Day was effected at a conference attended by representatives of interested commands.

Field testing of grenades, rifle, smoke, colored and various colored

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panels was undertaken by this office, ~~504th Airborne~~ Infantry ~~Regiments~~, and AFF Board No. 1 at the instance of the ~~Chief~~ ~~of~~ Army Field Forces. Results valuable to air ground operations were obtained.

In order to provide air strikes ~~effectiveness~~ against enemy targets discovered by fighter or reconnaissance pilots, a system was evolved in which spot reports were passed by the ~~combat operations officer~~ ~~xxxx~~ to the G-3 Air Action Officer who had ~~their~~ coordinates ~~checked~~ and determine desirability of laying on a strike. In the event that such a strike was decided upon, ~~a~~ request was ~~prepared on message form~~ and passed to an Air Target Officer, a specially designated officer in the Combat Operations Section charged with responsibility for processing ~~xxxxx~~ such requests immediately to the Chief Controller of the Tactical Air Control Center. Required aircraft, if available, were directed to such targets.

The question of who should decide where effort is to be placed on purely ground targets was posed by a situation in which enemy targets were reported by friendly aircraft proceeding toward the drop zone of ~~the~~ U.S. Airborne Division. As the tanks were sufficiently distant from the drop zone to constitute no imminent threat, considering time and distance factors, it was recommended that tanks be kept in view by reconnaissance aircraft. ~~be~~ ~~not~~ attacked by air alert aircraft. ~~unless~~, ~~the~~ aircraft on ground alert which had been ordered to take off to attack the target. ~~failed~~ to reach the area in sufficient time to prevent the tanks making contact with friendly forces. As an overall first priority had been prescribed for enemy tanks as ground targets, ~~and~~ immediate diversion of air alert aircraft was directed by Commander, TAF. As this would result in the airborne units being without air support in those critical hours immediately following their parachute landing, the G-3 Air ~~objection~~ to such a diversion ~~was~~ presented

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to the Commander, TAF. At that particular time, aircraft became available from an unexpected source, thus obviating the necessity for such a diversion.

Undoubtedly, the most vital problem faced in Exercise SWARMER in air ground coordination was xxxxxxxxx over-coming the inadequacy of the facilities of the 20th Signal Company, Air Ground Liaison. Operating with antiquated cypher devices, the converter, M209, and inexperienced cryptographic and communications personnel, the effective operation of the air ground team was very seriously hampered. Processing of encoded messages from Joint Operations Center to participating divisions, to include acknowledgement of receipt therefore, consumed as much as four hours and thirty-eight minutes. As it was impossible to use voice in most instances, a barrier was created which was never eliminated. Messages transmitted in the clear xxx required an excessive amount of time. The burden of administrative traffic and transmission of operational summaries over this net added a further burden to an already over-taxed facility.

The fact that the Forward Air Controllers arrived with the participating divisions at a late date and, in some instances, without their equipment, further contributed to the difficulties experienced in air ground operations. Lack of radio crystals and failure to make early distribution of authentication codes were additional factors impairing smooth coordination of air ground efforts.

During the period 30 April - 3 May 50 the Joint Operations Center received 212 Pre-planned Mission Requests and 15 On-Call Requests. Of the total of 227 requests received, 152 were completely processed and laid on by the Air Force. The 75 requests not laid on are broken down as follows:

20 were cancelled due to weather; 7 were cancelled by the Commanding General, V Corps; 10 were cancelled because they had previously been planned or laid on; 2 were cancelled after Visual Recce had been flown and no target located; 25 were disapproved by the G-3 Air Action Officer and 9 were

disapproved by the Combat Operations Officer. The total of 34 that were disapproved generally fall within one of the following classes; 1. Target of insufficient importance for Air Strike; 2. No allocation of aircraft available; 3. ~~Administrative Restriction~~ Problem limitations prohibiting accomplishment of ~~Mission~~ Requests.

The lack of time in which to compile this report precluded a thorough study of the operational phase of the exercise, and thus, has resulted in a report entirely inadequate to cover an ~~operation~~ exercise of this magnitude and importance.

RECOMMENDATIONS:

Control measures for anti-aircraft artillery fires should be included in early operational planning of all Headquarters and completely coordinated with all interested echelons prior to publication of their respective plans.

Airlift requirements for signal teams of the Signal Company, Air Ground Liaison should be ~~included~~ predicated to allow for their early arrival by the organizations with which they ~~are serving~~ to serve in the airhead.

Plans for the distribution of maps to Army units should include provisions for supplying such units with maps currently in use by Tactical Air Force, Air Support Aircraft, distributed down to and including line battalion commanders.

Provisions for supplying administrative and logistical services to such elements of the air ground operations system as may be serving with National Guard units should be coordinated with interested agencies prior to dispatch of such elements.

Joint Operations Center Briefing teams ~~in the JOC~~ should be sent to participating air and ground units to thoroughly acquaint ~~brief~~ them ~~on~~ with detailed plans of the operation. Coordination of flights of liaison type aircraft with those of high performance aircraft should be provided for in the operational plans of the interested Headquarters.

Successive air ground communications exercises should be conducted with a participating combat unit sufficiently prior to D-Day to permit correction of deficiencies noted and to afford maximum experience in processing air requests. Forward Air Controllers require additional experience in controlling aircraft prior to the mounting of an operation.

Maximum use should be made of maneuvers and exercises to field test new items of equipment.

A simple abbreviated form should be developed for use in processing requests for air strikes based on spot reports obtained from fighter and reconnaissance pilots in order that a permanent record may be available on one form of all information pertaining to such requests.

~~The representatives of~~ the ground commander ~~(G-2 Air and G-3 Air)~~ should have responsibility of final decision in determining an attack by aircraft against a purely ground target.

The best signal equipment currently available should be furnished by the 20th Signal Company, Air Ground Liaison, to enable them to meet their requirements furnishing expeditious air ground communications. Concerted effort should be placed upon research and development of electronic equipment capable of providing immediate, dependable and sincere air ground communications.

Forward Air Controllers and their equipment~~, completely~~ operative should ~~arrive~~ at the participating organizations at an early date in order to facilitate final phase training and participation in air ground communications exercises.

On-Call mission requests ~~must be submitted in larger numbers~~ in order to conserve available aircraft, but the processing of such requests require the communications system of the caliber outlined above. Pre-planned

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mission requests must be carefully screened ~~by xxx the G-3 Air, Corps Headquarters~~, prior to submission to the Air Ground Operations Section, JOC.

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1st Ind, Hq ConAC to USAF, Sub: Report on ORT Conference
18 April 1950 - 14 June 1950

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Hq USAF - (no file number)
Subject: Report on ORT Conference of 18 April 1950

AI 333.1 (10 May 50) 1st Ind 14 Jun 1950

HQ CONTINENTAL AIR COMMAND, Mitchel Air Force Base, New York

TO: The Inspector General, USAF, Hq United States Air Force
Washington 25, D. C.

1. In compliance with paragraph 3, basic letter, the changes recommended by this headquarters to item 28 of the present ORT criteria are attached as Inclosures 1 thru 8.

2. A narrative description of the manner of accomplishment of each phase should be made in the report, to include all matters preventing the effective accomplishment of the mission and the reasons therefor. Also, a rating of satisfactory or unsatisfactory should be awarded each item.

3. Case reports should be utilized where major irregularities and/or deficiencies exist which adversely affect the accomplishment of the unit mission.

4. It is recommended that an actual combat effectiveness score be awarded each unit and an explanation be included as to the basis upon which the score was awarded. This may be included on the cover sheet or as a final paragraph to the operational test sheet.

FOR THE COMMANDING GENERAL:

W. P. MULLINS
Lt. Col., USAF
Asst. Air Adj. Gen.

9 Incls
1. Score Sheet Ftr-Intcpr
2. Score Sheet Ftr-Bmr
3. Score Sheet Ftr-A/W
4. Score Sheet Lt Bomb (B-45)
5. Score Sheet Tac Rcn
6. Score Sheet Trp Carr (Med)
7. Score Sheet Trp Carr (Hvy)
8. Score Sheet AC&W (3 sections)
9. Score Sheet Tac Con (4 sections)

Log No. X11-42

2-3374-25

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SCORE SHEET FOR INTERCEPTOR - FIGHTER UNITS

1. SUSTAINED OPERATIONS - The ability to perform eight sorties per aircraft during a four-day period, utilizing 70% of the assigned aircraft twice daily. Aircraft committed must be combat ready.

2. FORMATION FLYING - The ability to maintain the integrity of a formation in accordance with sound tactics and techniques in all maneuvers within the limitations of the aircraft and the size of the formation employed. The unit must be capable of take-off, assembly and landing formations of various sizes in accordance with requirements of the unit training standard.

3. NAVIGATION - The ability to accomplish precision, maximum range navigational flights at the effective combat altitude of the aircraft; duration of each navigation sortie must be 90% of the fuel range specified in AF publications, less normal take-off and landing periods. Each aircraft must make good its ETA within 5% of the estimated total flight time.

4. INSTRUMENT FLYING

a. Individual

(1) Number of assigned pilots who hold a current USAF instrument rating.

(2) The ability to take off, climb, navigate, descend and land under minimum weather conditions, utilizing all available radio aids.

Incl #1

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Score Sheet for Interceptor-Fighter Units (contd)

b. Element and flight formation - The ability of a unit to penetrate weather by elements or flights with the wing man and/or second element maintaining position by visual reference to the lead aircraft.

c. Squadron penetration - The ability to ascend or descend through an overcast, utilizing time and space separation factors between flights with an orderly rendezvous above or below the overcast.

5. NIGHT FLYING - The ability to operate individually or by elements during the hours of darkness.

6. AERIAL GUNNERY - The ability of each pilot to fire and qualify in accordance with unit training standard. In the event it is not possible to conduct actual firing during the period of the ORT, a check of the records will be made to determine the number of pilots who have qualified during qualification firing within the previous year.

7. INTERCEPTION - The ability to operate in an air defense system under the direction of a ground controller. This includes the capability of immediate and precise execution of directions from the ground controller for changes in speed, vectors and altitudes, establishment of visual contact with the target, and

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employment of sound aggressive tactics in the attack. Scrambles from various stages of alert and ascent to altitude within time limits prescribed in appropriate unit training standard.

8. TURN-AROUND MISSIONS - The ability of the unit to service aircraft participating in turn-around missions within the time limits prescribed in applicable unit training standard.

9. RADIO PROCEDURES AND DISCIPLINE - Thorough knowledge and employment of established radio procedures (including appropriate JANAP's) and maintenance of air discipline.

10. NORMAL AND EMERGENCY PROCEDURES - Familiarity of pilots with normal and emergency procedures necessary for the operation of the aircraft. (Oxygen, pressurization, anti-G suits, crash-landing and ditching, etc.)

11. BRIEFING AND CRITIQUE - The ability to conduct efficient combat crew briefing and interrogation.

12. INTELLIGENCE

a. The ability to collect, collate, evaluate and disseminate military information in accordance with established procedures.

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Score Sheet for Interceptor-Fighter Units (contd)

b. Knowledge of the characteristics and recognition features of potentially hostile aircraft and missiles.

SCORE SHEET FOR FIGHTER-BOMBER UNITS

1. SUSTAINED OPERATIONS - The ability to perform eight sorties per aircraft during a four-day period, utilizing 70% of the assigned aircraft twice daily. Aircraft committed must be combat ready.

2. FORMATION FLYING - The ability to maintain the integrity of a formation in accordance with sound tactics and techniques in all maneuvers within the limitations of the aircraft and the size of the formation employed. The unit must be capable of take-off, assembly and landing formations of various sizes in accordance with requirements of the unit training standard.

3. NAVIGATION -

a. The ability to accomplish precision navigational flights at medium and effective combat altitude of the aircraft. Duration of each navigation sortie must be 90% of the fuel range specified in AF publications, less normal take-off and landing periods. Each aircraft must make good its ETA within 5% of the estimated total flight time.

b. The ability to navigate at very low altitude and locate predesignated pin-point targets.

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4. INSTRUMENT FLYING

   a. Individual

      (1) Number of assigned pilots who hold a current USAF instrument rating.

      (b) The ability to take off, climb, navigate, descend and land under minimum weather conditions utilizing all available radio aids.

   b. Element and flight formation - The ability of a unit to penetrate weather by elements or flights with the wing man and/or second element maintaining position by visual reference to the lead aircraft.

   c. Squadron penetration - The ability to ascend or descend through an overcast, utilizing time and space separation factors between flights with an orderly rendezvous above or below the overcast.

5. NIGHT FLYING - The ability to operate individually or by elements during the hours of darkness.

6. AERIAL GUNNERY - The ability of each pilot to fire and qualify in accordance with unit training standard. In the event it is not possible to conduct actual firing during the period of the ORT, a check of the records will be made to determine the number of pilots who have qualified during qualification firing within the previous year.

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Score Sheet for Fighter-Bomber Units (contd)

7. GROUND GUNNERY - The ability to fire upon a standard ground gunnery target and qualify in accordance with unit training standard. In the event it is not possible to conduct actual firing during the period of the ORT, a check of the records will be made to determine the number of pilots who have qualified during qualification firing within the previous year.

8. ROCKETRY - The ability to fire rockets upon a standard target and qualify in accordance with unit training standard. In the event it is not possible to conduct actual firing during the period of the ORT, a check of the records will be made to determine the number of pilots who have qualified during qualification firing within the previous year.

9. DIVE BOMBING - The ability to bomb and qualify in accordance with unit training standard. In the event it is not possible to conduct actual firing during the period of the ORT, a check of the records will be made to determine the number of pilots who have qualified during qualification firing within the previous year.

10. OPERATIONS UNDER RADAR CONTROL

a. The ability to accomplish interceptions of airborne targets under the direction of a ground controller. This includes the capability of immediate and precise execution of directions from the ground controller for changes in speed, vectors and altitudes, establishment of visual contact with the target and employment of sound aggressive tactics in the attack.

b. The ability to attack with guns, bombs and rockets enemy troops, installations and ground equipment, while under the direction of a forward controller and/or other units of a tactical control system.

11. RADIO PROCEDURES AND DISCIPLINE - Thorough knowledge and employment of established radio procedures (including appropriate JANAP's) and maintenance of air discipline.

12. NORMAL AND EMERGENCY PROCEDURES - Familiarity of pilots with normal and emergency procedures necessary for the operation of the aircraft. (Oxygen, pressurization, anti-G suits, crash-landing and ditching.)

13. BRIEFING AND CRITIQUE - The ability to conduct efficient combat crew briefing and interrogation.

14. INTELLIGENCE

a. The ability to collect, collate, evaluate and disseminate military information in accordance with established procedure.

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Score Sheet for Fighter-Bomber Units (contd)

b. Knowledge of the characteristics and recognition features of potentially hostile aircraft, missiles, and ground equipment and installations.

c. Knowledge of the capabilities and limitations of antiaircraft artillery and radar.

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SCORE SHEET FOR ALL-WEATHER FIGHTER UNITS

1. SUSTAINED OPERATIONS - The ability to furnish 70% of assigned aircraft in a combat ready condition to the AC&W controller for the fulfillment of his requirements.

2. NAVIGATION - The ability to accomplish precision, maximum range navigational flights under instrument conditions, actual or simulated (the latter to be used when actual instrument conditions do not prevail) at the effective combat altitude of the aircraft. Duration of each navigation sortie must be 90% of the fuel range specified in AF publications, less normal take-off and landing periods. Each aircraft must make good its ETA within 5% of the estimated total flight time.

3. INSTRUMENT FLYING

a. Number of assigned pilots who hold a current USAF instrument rating.

b. The ability to take off, accomplish any mission required of all-weather fighter aircraft and land under minimum weather conditions, utilizing all available radio and electronic aids.

4. NIGHT FLYING - The ability to conduct any mission required of all-weather fighter units under conditions of darkness.

Incl #3

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Score Sheet for All-Weather Fighter Units (contd)

5. AERIAL GUNNERY - The ability of each pilot to fire and qualify in accordance with unit training standard (day and night). In the event it is not possible to conduct actual firing during the period of the ORT, a check of the records will be made to determine the number of pilots who have qualified during qualification firing within the previous year.

6. INTERCEPTION - The ability to operate in an air defense system under the direction of a ground controller. This includes the capability of immediate and precise execution of directions from the ground controller for changes in speed, vectors and altitudes, assumption of AI control and tracking, positioning and attacking the target by use of airborne electronic equipment. Scrambles from various stages of alert and ascent to altitude within time limits prescribed in appropriate unit training standard.

7. TURN-AROUND MISSIONS - The ability of the unit to service aircraft participating in turn-around missions within the time limits prescribed in applicable unit training standard.

8. RADIO PROCEDURES AND DISCIPLINE - Thorough knowledge and employment of established radio procedures (including appropriate JANAP's) and maintenance of air discipline.

Score Sheet for All-Weather Fighter Units (contd)

9. NORMAL AND EMERGENCY PROCEDURES - Familiarity of pilots with normal and emergency procedures necessary for the operation of the aircraft. (Oxygen, pressurization, anti-G suits, crash-landing and ditching, etc.)

10. BRIEFING AND CRITIQUE - The ability to conduct efficient combat crew briefing and interrogation.

11. INTELLIGENCE

a. The ability to collect, collate, evaluate and disseminate military information in accordance with established procedure.

b. Knowledge of the characteristics and recognition features of potentially hostile aircraft and missiles.

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SCORE SHEET FOR LIGHT BOMBARDMENT (B-45) UNITS

1. SUSTAINED OPERATIONS - Unit must be capable of performing three missions of normal combat radius for the B-45 type aircraft within a four-day period, utilizing an average of 70% of the assigned aircraft per mission.

2. ASSEMBLY AND FORMATION

   a. The ability to take off and assemble a 12-aircraft formation under VFR conditions within 10 minutes.

   b. The ability to land a 12-aircraft formation under VFR conditions within six minutes.

   c. The ability to maintain the integrity of a formation in all maneuvers within the limitations of the aircraft and the size of the formation employed.

3. NAVIGATION - The ability to accomplish precision, maximum range navigational flights at medium and high altitudes, utilizing electronic aids and dead-reckoning. Duration of each navigation sortie must be 90% of the fuel range specified in AF publications, less normal take-off and landing periods. Each aircraft must make good its ETA within 5% of the estimated total flight time.

4. INSTRUMENT FLYING

   a. Number of assigned pilots who hold a current USAF instrument rating.

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Score Sheet for Light Bombardment (B-45) Units (contd)

b. The ability to take off, ascend, navigate, descend and land under minimum weather conditions utilizing all available radio and electronic aids.

c. The ability to take off individually, ascend through an overcast and assemble 12 aircraft in formation above the overcast.

5. NIGHT FLYING - The ability to operate individually and/or in formation on tactical missions during the hours of darkness.

6. BOMBING - The ability to locate, identify and accurately bomb briefed targets.

7. OPERATIONS UNDER RADAR CONTROL - The ability to attack targets in the vicinity of friendly troops while operating under the direction of a forward controller and/or other units of a tactical control system.

8. RADIO PROCEDURES AND DISCIPLINE - Thorough knowledge and employment of established radio procedures (including appropriate JANAP's) and maintenance of air discipline.

9. NORMAL AND EMERGENCY PROCEDURES - Familiarity of pilots with normal and emergency procedures necessary for the operation of the aircraft. (Oxygen, pressurization, crash-landing and ditching, etc.)

Score Sheet for Light Bombardment (B-45) Units (contd)

10. BRIEFING AND CRITIQUE - The ability to conduct efficient combat crew briefing and interrogation.

11. INTELLIGENCE

a. The ability to collect, collate, evaluate and disseminate military information in accordance with established procedure.

b. Knowledge of the characteristics and recognition features of potentially hostile aircraft and missiles, and ground equipment and installations.

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SCORE SHEET FOR TACTICAL RECONNAISSANCE UNITS

1. SUSTAINED OPERATIONS - The ability to keep an average of 70% of assigned aircraft combat ready during period of test.

2. NAVIGATION - The ability to accomplish precision, maximum range navigational flights, utilizing electronic aids and dead-reckoning. Duration of each navigational sortie must be 90% of the fuel range specified in AF publications, less normal take-off and landing periods. Each aircraft must make good its ETA within 5% of the estimated total flight time.

3. INSTRUMENT FLYING -
   a. Number of assigned pilots who hold a current USAF instrument rating.
   b. Ability to take off, climb, navigate, descend, and land under minimum weather conditions, utilizing all available radio aids.

4. NIGHT FLYING - The ability to operate during the hours of darkness within the scope of night operations required of tactical reconnaissance units.

5. VISUAL RECONNAISSANCE
   a. The ability to conduct visual reconnaissance and report information on location and/or movement of ground and naval surface formations, equipment and installations.

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Score Sheet for Tactical Reconnaissance Units (contd)

b. The ability to operate with accuracy in conjunction with artillery and naval units on adjustment missions.

6. PHOTOGRAPHIC RECONNAISSANCE

a. The ability to obtain photographic coverage of pin-point targets, strips and mosaics by use of all types of camera installations capable of being employed in the aircraft.

b. The ability to develop, print and provide first phase photo interpretation within time required by unit training standard after completion of a mission.

7. RADIO PROCEDURES AND DISCIPLINE - Thorough knowledge and employment of established radio procedures (including appropriate JANAP's) and maintenance of air discipline.

8. NORMAL AND EMERGENCY PROCEDURES - Familiarity of pilots with normal and emergency procedures necessary for the operation of the aircraft. (Oxygen, pressurization, crash-landing and ditching, etc.)

9. BRIEFING AND CRITIQUE - The ability to conduct efficient combat crew briefing and interrogation.

10. INTELLIGENCE AND MISSION PLANNING

Score Sheet for Tactical Reconnaissance Units (contd)

a. The ability to collect, collate, evaluate and disseminate military information in accordance with established procedures.

b. Knowledge of the characteristics and recognition features of potentially hostile aircraft, missiles, and ground equipment and installations.

c. The ability to plan, coordinate, dispatch and supervise missions directed by higher headquarters.

11. TURN-AROUND MISSIONS - The ability of the unit to service aircraft participating in turn-around missions within the time limits prescribed in applicable unit training standard.

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SCORE SHEET FOR TROOP CARRIER UNITS (MEDIUM)

1. SUSTAINED OPERATIONS - The ability of the unit to keep 75% of the assigned aircraft in the air for the missions required during the four-day period of the test. (A minimum of 3 missions to be scheduled.)

2. FORMATION FLYING

   a. The ability to take off and assemble a nine-aircraft formation under VFR conditions within eight minutes.

   b. The ability to take off and assemble a nine-aircraft formation with gliders (for units so equipped) under VFR conditions within 14 minutes.

   c. The ability to maintain the integrity of a formation in accordance with troop carrier tactics and techniques during all maneuvers within the limitations of the aircraft and the size of the formation employed.

   d. The ability to land a nine-aircraft formation under VFR conditions within seven minutes.

3. NAVIGATION - The ability to accomplish precise, maximum range navigational flights, arriving over a designated point within one minute of the briefed time.

4. INSTRUMENT FLYING

   a. Individual

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(1) Number of assigned pilots who hold a current USAF instrument rating.

(2) The ability to take off, climb, navigate, descend and land under minimum weather conditions utilizing all available radio aids.

b. Element and Flight Formation - The ability of a unit to penetrate weather by elements or flights with the wing man and/or second element maintaining position by visual reference to the lead aircraft.

c. Squadron penetration - The ability to ascend or descend through an overcast, utilizing time and space separation factors between flights with an orderly rendezvous above or below the overcast.

5. NIGHT FLYING - The ability to operate individually and in formation on tactical missions during the hours of darkness.

6. PARATROOP OPERATIONS

a. The ability to locate a DZ through utilization of pathfinder equipment and techniques, and by use of maps and photos; and the ability to deliver an airborne unit to the designated DZ within one minute of the briefed time.

b. The ability to utilize appropriate formation and to position and drop troops into a limited area, the size of which will

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be commensurate with the assigned tactical mission.

7. RESUPPLY

a. The ability to deliver supply bundles by parachute into a limited area, the size of which will be commensurate with the tactical mission.

b. The ability to deliver troops and equipment into a designated air landing area on schedule.

8. GLIDER OPERATIONS (FOR UNITS SO EQUIPPED)

a. The ability to take off, assemble in formation and deliver gliders to a designated landing zone within one minute of the briefed time over target.

b. The ability to conduct glider pick-up operations in accordance with standard troop carrier tactics and techniques.

9. AIR EVACUATION - The ability to conduct air evacuation missions, including the setting up of litters and equipment, in-flight feeding, and proper procedure for care of sick and wounded.

10. RADIO PROCEDURES AND DISCIPLINE - Thorough knowledge and employment of established radio and interphone procedures (including appropriate JANAP's), and maintenance of air discipline.

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11. NORMAL AND EMERGENCY PROCEDURES - Thorough knowledge of all normal and emergency procedures applicable to the safe operation of the aircraft; knowledge of the methods of abandoning, crash-landing and ditching the aircraft; familiarity with the proper use of life-saving equipment with which provided.

12. BRIEFING AND CRITIQUE - The ability to conduct efficient combat crew briefing and interrogation.

13. INTELLIGENCE - The ability to collect, collate, evaluate and disseminate military information in accordance with established procedures.

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SCORE SHEET FOR TROOP CARRIER UNITS (HEAVY)

1. SUSTAINED OPERATIONS - The ability of the unit to keep 75% of the assigned aircraft in the air for the missions required during the four-day period of the test. (A minimum of 3 missions to be scheduled.)

2. FORMATION -

   a. The ability to take off and assemble a six-aircraft formation under VFR conditions within eight minutes.

   b. The ability to maintain the integrity of a formation in accordance with troop carrier tactics and techniques during all maneuvers within the limitations of the aircraft and the size of the formation employed.

   c. The ability to land a six-aircraft formation under VFR conditions within five minutes.

3. NAVIGATION - The ability to accomplish precise, maximum range navigational flights, arriving over a designated point within one minute of the briefed time.

4. INSTRUMENT FLYING

   a. Individual

      (1) Number of assigned pilots who hold a current USAF instrument rating.

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(2) The ability to take off, climb, navigate, descend and land under minimum weather conditions, utilizing all available radio aids.

b. Element and Flight Formation - The ability of a unit to penetrate weather by elements or flights with the wing man and/or second element maintaining position by visual reference to the lead aircraft.

c. Squadron penetration - The ability to ascend or descend through an overcast, utilizing time and space separation factors between flights with an orderly rendezvous above or below the overcast.

5. NIGHT FLYING - The ability to operate individually and in formation on tactical missions during the hours of darkness.

6. AIR EVACUATION - The ability to conduct air evacuation missions, including the setting up of litters and equipment, in-flight feeding, and proper procedure for care of sick and wounded.

7. AIRLIFT - The ability to deliver troops and/or equipment into a designated area on schedule and in accordance with the assigned tactical mission.

8. RADIO PROCEDURES AND DISCIPLINE - Thorough knowledge and employment of established radio and interphone procedures (including

appropriate JANAP's) and maintenance of air discipline.

9. NORMAL AND EMERGENCY PROCEDURES - Thorough knowledge of all procedures applicable to the safe operation of the aircraft; knowledge of the method of abandoning, crash-landing and ditching the aircraft; familiarity with the proper use of life-saving equipment with which provided.

10. BRIEFING AND CRITIQUE - The ability to conduct efficient combat crew briefing and interrogation.

11. INTELLIGENCE - The ability to collect, collate, evaluate and disseminate military information in accordance with established procedures.

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SCORE SHEET FOR AIRCRAFT CONTROL AND WARNING UNITS

SECTION I - AIR DEFENSE CONTROL CENTER

(Overall effectiveness to be based on applicable TO&E authorizations and assigned mission.)

1. PRESENTATION OF AIR SITUATION - Ability of the control center to present clearly a continuous and timely representation of the air picture. Ability of the unit to collect and disseminate to all control personnel special information concerning the capabilities, limitations and tactics of friendly and hostile forces. Ability of the center to display continuously all applicable air surveillance, aircraft, communications and radar status, movement-identification, and weather information as rapidly as secured.

2. COMMUNICATIONS OPERATIONS - Ability of the unit to utilize efficiently organic communications facilities and equipment. Ability of the unit to transmit information on air activity, as rapidly as collected, to interested installations and agencies. Ability of the unit to utilize all available means to minimize the effects of enemy jamming operations. Adequacy of communications security and net discipline. Adeptness of operating personnel in use of applicable grid systems, codes, authentication systems, and operation logs.

3. IDENTIFICATION - Ability of the unit to identify all friendly aircraft through knowledge of flight plans, radar data and other related information. Expeditious accomplishment of confirmation or changing of hostile identification of tracks after reporting to the control center. Provision for supplying air raid warning information to civilian and military authorities.

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4. COMBAT OPERATIONS - Ability of the control center to utilize information of the air situation in effectively employing fighter aircraft and AAA. Ability of the control center to co-ordinate the utilization of all air defense activities within the area, to include the necessary coordination with higher and adjacent units required by mutual air defense operations. Provisions for coordinating and supervising air rescue and navigational assistance to friendly air activity. Coordination and supervision of all air surveillance units in maintaining continuous, complete air surveillance coverage of the area. Ability to conduct efficient briefings and critiques.

5. INTELLIGENCE - Ability of the unit to collect information of all friendly aircraft movements in the area and other intelligence concerning air operations, and analyze, evaluate and disseminate this information to air units or agencies as required.

6. SECURITY - Adequacy of precautionary measures to safeguard equipment and personnel. Establishment of an adequate unit defense plan consistent with organic capabilities.

SCORE SHEET FOR AIRCRAFT CONTROL AND WARNING UNITS

SECTION II - GCI RADAR STATION

(Overall effectiveness to be based on applicable TO&E authorization and assigned mission.)

1. RADAR OPERATIONS - The ability efficiently to operate organic radar and IFF equipment, reporting the data obtained with a minimum time delay according to SOP's. The ability to establish air surveillance of a designated sector to include: detection of aircraft; height determination of tracks; electronic interrogation of tracks; display of position; height; IFF; and estimated number of aircraft. Indoctrination of personnel in the recognition of hostile countermeasures activity and the employment of anti-jamming measures.

2. PRESENTATION OF THE AIR SITUATION - Ability of the unit to present clearly a continuous and timely representation of the air picture. The ability to report to the control center the position, direction, number of aircraft, height and identification, as rapidly as such information is displayed. Effectiveness of cross-telling between stations.

3. COMBAT OPERATIONS - Ability of the unit to utilize properly air information in controlling combat forces. Ability to identify all aircraft in the sector within one minute after display of initial plot. Ability of unit to control two flights simultaneously per control scope, coordinate all air activities within the

sector and with adjoining sectors, provide navigational assistance to friendly aircraft lost or in distress, and provide air raid warning information to civil and military agencies, to include AAA. Ability to conduct efficient briefings and critiques.

4. COMMUNICATIONS OPERATIONS - Ability of the unit to utilize efficiently organic communications equipment. Capability of communications operating personnel to utilize applicable communications operating procedures, as prescribed in USAF publications and JANAP's. Adeptness of operating personnel in use of applicable grid systems, codes, authenticator systems, and operation logs. Adequacy of communications security and net discipline. Employment of correct fighter director R/T code in accordance with JANAP 142B.

5. SECURITY - Adequacy of precautionary measures to safeguard equipment and personnel. Establishment of an adequate unit defense plan consistent with organic capabilities.

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SCORE SHEET FOR AIRCRAFT CONTROL AND WARNING UNITS

SECTION III - EARLY WARNING RADAR STATION

(Overall effectiveness to be based on applicable TO&E authorizations and assigned mission.)

1. RADAR OPERATIONS - The ability of the unit efficiently to operate organic radar and IFF equipment; report the data obtained with a minimum time delay according to SOP's; identify all air activity in its area of responsibility within one minute after display of initial plot; obtain and report radar weather information; recognize hostile counter-measures and employ anti-jamming measures; perform intercept missions under VFR conditions and conduct efficient briefings and critiques.

2. COMMUNICATIONS OPERATIONS - The ability of the unit efficiently to utilize organic communications equipment; employ applicable communications operating procedures as prescribed in USAF publications and JANAP's; utilize applicable grid systems, codes, authentication systems and operation logs; rapidly transmit air activity information to all interested agencies or installations; employ adequate communications security and net discipline; coordinate with higher and adjacent units when required for mutual air surveillance operations; and utilize correct fighter director R/T code in accordance with JANAP 142B.

Score Sheet for Aircraft Control and Warning Units (contd)

3. SECURITY - Adequacy of precautionary measures to safeguard equipment and personnel. Establishment of adequate unit defense plan consistent with organic capabilities.

SCORE SHEET FOR TACTICAL CONTROL UNITS - SECTION I -

TACTICAL AIR CONTROL CENTER

(Overall effectiveness to be based on applicable TO&E authorization and assigned mission.)

1. PRESENTATION OF AIR SITUATION - Ability of the control center to present clearly a continuous and timely representation of the air picture. Ability of the unit to collect and disseminate to all control personnel special information concerning the capabilities, limitations and tactics of friendly and hostile forces. Ability of the center to display continuously all applicable air surveillance, aircraft, communications and radar status, movement-identification, and weather information as rapidly as secured.

2. COMMUNICATIONS OPERATIONS - Ability of the unit to utilize efficiently organic communications facilities and equipment. Ability of the unit to transmit information on air activity, as rapidly as collected, to interested installations and agencies. Ability of the unit to utilize all available means to minimize the effects of enemy jamming operations. Adequacy of communications security and net discipline. Adeptness of operating personnel in use of applicable grid systems, codes, authentication systems, and operation logs.

3. IDENTIFICATION - Ability of the unit to identify all friendly aircraft through knowledge of flight plans, radar data and other related information. Expeditious accomplishment of confirmation or changing of hostile identification of tracks after reporting to the control center. Provision for supplying air raid warning information to civilian and military authorities.

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4. COMBAT OPERATIONS

a. Ability of the control center to utilize information of the air situation in effectively employing fighter aircraft and AAA. Ability of the control center to coordinate the utilization of all air defense activities within the area, to include the necessary coordination with higher and adjacent units required by mutual air defense operations. Provisions for coordinating and supervising air rescue and navigational assistance to friendly air activity. Coordination and supervision of all air surveillance units in maintaining continuous, complete air surveillance coverage of the area. Ability to conduct efficient briefings and critiques.

b. Offensive. Ability of chief controller, upon receipt of operations orders from joint operations center, to hold briefings during which missions are assigned to individual controllers; adequacy of briefings as to bomb safety lines, friendly air and ground intelligence, enemy air and ground intelligence, particularly enemy AAA positions. Techniques of individual controllers during accomplishment of request or call mission. Ability of controllers to keep fighters and direction centers supplied with the latest target and intelligence information. Ability of the controller in charge of air defense to keep himself continually abreast of the tactical situation as regards routes of friendly fighter aircraft engaged in support missions, and flight plans of friendly cargo, troop-carrying and reconnaissance aircraft; his ability to act as movements-identification officer and utilize this information to assist the tactical air direction centers having direct control of the Combat Air Patrol fighter aircraft. Ability of the control center parties either direct or through the direction centers. Efficiency and dispatch of the chief controller in analyzing a tactical situation, making a command decision thereon, or recommending action to the joint operations center. Utilization to the maximum degree of pin-point radar bombing facilities of the tactical air direction posts.

5. INTELLIGENCE - Ability of the unit to collect information of all friendly aircraft movements in the area and other intelligence concerning air operations, and anlyze, evaluate and disseminate this information to air units or agencies as required.

6. SECURITY - Adequacy of precautionary measures to safeguard equipment and personnel. Establishment of an adequate unit defense plan consistent with organic capabilities.

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SCORE SHEET FOR TACTICAL CONTROL UNITS

SECTION II - TACTICAL AIR DIRECTION CENTER

(Overall effectiveness to be based on applicable TO&E authorizations and assigned mission.)

1. RADAR OPERATIONS - The ability efficiently to operate organic radar and IFF equipment, reporting the data obtained with a minimum time delay according to SOP's. The ability to establish air surveillance of a designated sector, to include: detection of aircraft; height determination of tracks; electronic interrogation of tracks; display of position; height; IFF; and estimated number of aircraft. Indoctrination of personnel in the recognition of hostile countermeasures activity and the employment of anti-jamming measures.

2. PRESENTATION OF THE AIR SITUATION - Ability of the unit to present clearly a continuous and timely representation of the air picture. The ability to report to the control center the position, direction, number of aircraft, height and identification, as rapidly as such information is displayed. Effectiveness of cross-telling between stations.

3. COMBAT OPERATIONS

a. Defensive - Ability of the unit to utilize properly air information in controlling combat forces. Ability to identify

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all aircraft in the sector within one minute after display of initial plot. Ability of unit to control two flights simultaneously per control scope, coordinate all air activities within the sector and with adjoining sectors, provide navigational assistance to friendly aircraft lost or in distress, and provide air raid warning information to civil and military agencies, to include AAA. Ability to conduct efficient briefings and critiques.

b. Offensive. Ability of chief controller to brief all control personnel upon receipt of operations orders. Adequacy of briefings as to the current ground situation, friendly and enemy air activity, location of bomb-safety lines and concentrations of enemy AAA. Effectiveness in charting of ground situation in assisting individual controllers in carrying out support missions. Ability of individual controllers to supply aircraft with target and en route information during request missions. Ability of the unit during request missions to maintain close contact with the tactical air control parties and to keep them informed well in advance as to the identification, numbers, and approach direction of fighter-bombers. Efficiency and dispatch of the chief controller in analyzing a tactical situation, in making a command decision thereon, or in making recommendations to the tactical air control center.

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Score Sheet for Tactical Control Units
Section II - Tactical Air Direction Center (contd)

4. COMMUNICATIONS OPERATIONS - Ability of the unit to utilize efficiently organic communications equipment. Capability of communications operating personnel to utilize applicable communications operating procedures as prescribed in USAF publications and JANAP's. Adeptness of operating personnel in use of applicable grid systems, codes, authenticator systems, and operation logs. Adequacy of communications security and net discipline. Employment of correct fighter director R/T code in accordance with JANAP 142B.

5. SECURITY - Adequacy of precautionary measures to safeguard equipment and personnel. Establishment of an adequate unit defense plan consistent with organic capabilities.

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SCORE SHEET FOR TACTICAL CONTROL UNITS

SECTION III - TACTICAL AIR CONTROL PARTY

(Overall effectiveness to be based on applicable TO&E authorization and assigned mission.)

1. COMBAT OPERATIONS - The ability of the unit efficiently to advise army unit commander as to selection of air targets; make sound recommendations on request missions as to aircraft and bomb-load requirements; display good judgment when working directly with supporting aircraft; continually inform pilots as to target movements, enemy automatic weapon and heavy AAA concentrations in the target area, and the position of friendly troops and armor; recommend correct and effective use of marker smoke or flares to assist bomber aircraft; make effective recommendations for the routes of reconnaissance aircraft; and maintain adequate contact with the rear elements of the tactical control group.

2. COMMUNICATIONS OPERATIONS - The ability of the unit efficiently to utilize organic communications equipment; and employ correct voice procedures, security measures and authentication systems. Maintenance of proper radio discipline.

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SCORE SHEET FOR TACTICAL CONTROL UNITS

SECTION IV - TACTICAL AIR DIRECTION POST

(Overall effectiveness to be based on applicable TO&E authorization and assigned mission.)

1. COMBAT OPERATIONS - Ability of chief controller to brief all control personnel upon receipt of operations orders. Adequacy of briefings as to the current ground situation, friendly and enemy air activity, location of bomb-safety lines and concentrations of enemy AAA. The ability of the unit efficiently to operate organic radar equipment. Effectiveness in charting ground situation to carry out support missions. The ability to direct aircraft by electronic means to target and when to drop bombs. The ability to direct aircraft in precision navigation. Efficiency and dispatch of the chief controller in analyzing a tactical situation and making recommendations to the tactical air direction center.

2. COMMUNICATIONS OPERATIONS - Ability of the unit efficiently to utilize organic communications equipment. Capability of communications operating personnel to utilize applicable communications operating procedures as prescribed in USAF publications and JANAP's. Adeptness of operating personnel in use of applicable grid systems, codes, authenticator systems, and operations logs. Adequacy of communications security and net

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discipline. Employment of correct fighter director R/T code in accordance with JANAP 142B.

3. SECURITY - Adequacy of precautionary measures to safeguard equipment and personnel. Establishment of an adequate unit defense plan consistent with organic capabilities.

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Air Reserve Officer's
Training Corps Enrollment Data
1 March 1949

AIR RESERVE OFFICERS' TRAINING CORPS ENROLLMENT DATA

By Air Force

(Including White and Negro Personnel)

As of 1 March 1949

AIR FORCE	NO. OF INSTITUTIONS	STUDENTS FORMALLY ENROLLED			
		ELEMENTARY		ADVANCED	
		1st Yr	2nd Yr	1st Yr	2nd Yr
First Air Force	15	2230	1171	606	291
Fourth Air Force	18	3117	1409	803	545
Ninth Air Force	19	4136	2165	883	590
Tenth Air Force	31	5636	2863	1469	755
Twelfth Air Force	12	2360	1206	890	544
Fourteenth Air Force	15	1895	1313	761	596
TOTAL	110	19374	10127	5412	3321

NOTE: Detailed Listing of ROTC Institutions and Enrollment Data on following pages.

SOURCE: Air ROTC Enrollment Report (RCS ARC-SC-P2B)

PREPARED BY: Headquarters Continental Air Command, Office of Statistical Services.

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REPORT OF AIR ROTC STUDENTS

As of 1 March 1949

TABLE I TRAINING DATA

Air ROTC Training A	Students Formally Enrolled B	Other S[illegible] C
	WHITE	
1st Year Basic	19066	50
2nd Year Basic	9939	17
1st Year Advanced	5328	85
2nd Year Advanced by course title		
Supply	320	2
Administration	1496	10
Communications	236	1
Statistical Control	263	2
Transportation	182	1
Maintenance	572	5
Armament	163	-
Total 2nd Year Advanced	3232	21
TOTAL WHITE	37565	153
	NEGRO	
1st Year Basic	308	-
2nd Year Basic	188	-
1st Year Advanced	84	-
2nd Year Advanced by course title		
Supply	15	-
Administration	3	-
Communications	-	-
Statistical Control	4	-
Transportation	66	-
Maintenance	1	-
Armament	-	-
Total 2nd Year Advanced	89	-
TOTAL NEGRO	669	-

REPORT OF AIR ROTC STUDENTS

As of 1 March 1949

TABLE II COMMUTATION SUBSISTENCE AND UNIFORM DATA

	Total (B,C,D&E) A	1st Year Basic B	2nd Year Basic C	1st Year Advanced D	2nd Year Advanced E
WHITE					
1. Receiving Commutation Subsistence	6283	-	-	5176	3107
2. Receiving Commutation Uniforms	5836	1052	707	2593	1484
3. Drawing Issue Uniforms	31546	17967	9231	2703	1745
4. Drawing Neither Commutation Nor Issue Uniforms	83	47	1	32	3
5. Uniforms on Hand	14935	8608	3438	1793	1086
6. Eligible for commission in USAFR at end of current school year	2454	-	-	-	2454
NEGRO					
1. Receiving Commutation Subsistence	172	-	..	83	89
2. Receiving Commutation Uniforms	19	1	-	12	6
3. Drawing Issue Uniforms	650	307	[illegible]	72	83
4. Drawing Neither Commutation Nor Issue Uniforms	-	-	-	-	-
5. Uniforms On Hand	4	4	-	-	-
6. Eligible for commission in USAFR at end of current school year	47	-	-	-	47

REPORT OF AIR ROTC STUDENTS

As of 1 March 1949

TABLE III SCHOOL SUMMARY

	Students Formally Enrolled			
	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
			WHITE	
First Air Force				
Boston University	154	79	36	16
Colgate University	103	14	25	13
University of Connecticut	262	32	56	31
Cornell University	214	149	46	14
Fordham University	181	89	54	41
Harvard University	65	20	31	18
University of Massachusetts	109	100	[illegible]	15
Massachusetts Institute of Tech	155	150	[illegible]	14
University of New Hampshire	167	113	[illegible]	32
New York University	189	116	[illegible]	28
Rutgers University	227	227	[illegible]	13
University of Syracuse	63	30	[illegible]	37
Trinity College	83	-	[illegible]	-
Williams College	103	[illegible]	[illegible]	5
Yale University	152	[illegible]	[illegible]	23
TOTAL	2227	1168	[illegible]	290
Fourth Air Force				
Oregon State Agricultural Col.	247	164	48	41
Stanford University	104	22	26	22
University of Oregon	274	130	29	[illegible]
University of Arizona	237	139	44	[illegible]
San Jose State College	61	28	47	60
State College of Washington	280	159	-	-
University of Utah	116	24	63	54
University of California (Los Angeles)	264	168	36	47
Montana State University	130	90	26	7
Montana State College	137	105	22	7
Loyola University	151	73	28	-
University of Washington	371	20	65	74
Arizona State College	193	21	20	1
University of Southern California	38	8	[illegible]	15
University of Nevada	97	53	32	14
Utah State Agricultural College	238	129	172	102
Fresno State College	50	[illegible]	21	-
University of Idaho	120	70	[illegible]	39
TOTAL	3108	1409	[illegible]	545

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REPORT OF AIR ROTC STUDENTS

As of 1 March 1949

TABLE III SCHOOL SUMMARY

	Students Formally Enrolled			
	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
			WHITE	
Ninth Air Force				
Western Kentucky State College	67	48	13	7
University of Kentucky	347	204	86	61
University of Cincinnati	181	53	73	78
Ohio State University	628	266	65	45
Ohio University	279	207	42	7
Lehigh University	201	113	33	[illegible]
The Penn State College	471	194	59	[illegible]
Virginia Polytechnic Institute	156	100	64	29
West Virginia University	211	158	47	[illegible]
University of Maryland	505	281	37	[illegible]
Gettysburg College	57	31	15	16
University of Pennsylvania	103	34	37	21
Duquesne University	204	99	49	29
Johns Hopkins University	122	38	25	13
University of Pittsburgh	121	70	59	55
University of Akron	130	62	38	25
Georgetown University	95	31	[illegible]	25
Virginia Military Institute	73	60	[illegible]	34
TOTAL	3951	2047	[illegible]	557
Tenth Air Force				
University of Illinois	226	170		18
Coe College	78	42		16
Iowa State	334	176		31
University of Iowa	293	212	[illegible]	29
University of Minnesota	145	17	[illegible]	60
University of Wisconsin	238	147	42	19
University of Missouri	336	237	71	50
University of St Louis	326	51	137	39
Kansas State	242	155	56	27
University of Wichita	75	41	35	30
University of Kansas	61	33	50	74
University of Nebraska	206	116	45	28
Colorado State	278	160	57	[illegible]
University of Denver	20	12	63	[illegible]
University of Wyoming	119	103	22	8
North Dakota Agricultural College	161	104	24	11
University of North Dakota	114	77	30	7
South Dakota State College of A&MA	134	96	30	10

Cont'd

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REPORT OF AIR ROTC STUDENTS

As of 1 March 1949

TABLE III SCHOOL SUMMARY

	Students Formally Enrolled			
	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
			WHITE	
Tenth Air Force Cont'd				
St Thomas College	312	108	[illegible]	-
Wisconsin State Teachers College	84	-	[illegible]	-
Bradley University	112	-	27	-
Washburn Municipal University	61	5	[illegible]	-
Notre Dame University	111	48	[illegible]	27
Purdue University	233	168	[illegible]	24
University of Indiana	511	325	[illegible]	51
Ball State	105	8	[illegible]	-
Butler University	58	-	27	-
University of Michigan	113	24	41	[illegible]
Michigan State College	317	182	92	[illegible]
Michigan College of M&T	99	21	52	22
Wayne University	109	18	34	15
TOTAL	5611	2856	1458	[illegible]
Twelfth Air Force				
University of Arkansas	161	91	51	57
New Mexico A & M	99	34	41	23
Oklahoma A & M	306	170	68	45
University of Oklahoma	307	215	82	[illegible]
Texas A & M	587	285	208	144
Texas School of Technology	108	40	54	60
University of Texas	97	54	[illegible]	69
Louisiana State University	247	175	[illegible]	40
Tulane University	87	35	33	38
Southwestern La. Institute	221	-	[illegible]	-
Southern Methodist University	48	84	[illegible]	-
Baylor University	92	23		-
TOTAL	2360	1206	[illegible]	544

REPORT OF AIR ROTC STUDENTS

As of 1 March 1949

TABLE III SCHOOL SUMMARY

	Students Formally Enrolled			
	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
		WHITE		
Fourteenth Air Force				
Ala Polytechnic Institute	174	97	47	59
University of Alabama	318	202	[illegible]	63
The Citadel	82	70	64	37
Clemson College	101	120	58	41
Georgia School of Technology	104	77	55	27
University of Georgia	80	49	46	51
Mississippi State College	146	98	66	[illegible]
University of Mississippi	83	50	41	[illegible]
University of Florida	283	228	79	[illegible]
University of Miami	111	54	37	[illegible]
North Carolina State College	168	113	42	[illegible]
East Carolina Teachers College	35	3	33	-
University of North Carolina	78	58	57	32
University of Tennessee	46	34	20	27
TOTAL	1809	1253	730	544
GRAND TOTAL	19066	9939	[illegible]	3232

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REPORT OF AIR ROTC STUDENTS

As of 1 March 1949

TABLE III SCHOOL SUMMARY

NEGRO

	Students Formally Enrolled			
	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
First Air Force				
Fordham	2	1	-	
Massachusetts	-	1	-	-
New York University	1	1	-	1
TOTAL	3	3		1
Fourth Air Force				
Loyola University	4	-	-	-
Arizona State	4	-	-	-
Fresno State	1	-	1	-
TOTAL	9		1	
Ninth Air Force				
Ohio State University	50	30		1
Howard University	125	81	30	28
University of Pennsylvania	-	-	1	1
Duquesne University	2	1	-	-
University of Pittsburgh	3	3		3
University of Akron	5	3	-	-
TOTAL	185	118	31	33
Tenth Air Force				
University of Illinois	-	1	1	1
University of Iowa	4	2	-	-
University of Wisconsin	1	-	-	-
University of St Louis	7	-	3	-
University of Wichita	1	-	-	-
University of Kansas	-	1	1	-
Colorado State	1	-	-	-
University of Denver	-	1	-	-
Bradley University	1	-	-	-
Washburn Municipal University	3	-	-	-
University of Indiana	-	-	-	1
University of Michigan	1	1	-	-
Michigan State	1	-	2	-
Wayne University	5	1	4	1
TOTAL	25	7	11	3

REPORT OF AIR ROTC STUDENTS

As of 1 March 1949

TABLE III SCHOOL SUMMARY

	Students Formally Enrolled			
	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
		NEGRO		
Fourteenth Air Force				
Tuskegee	86	60	31	52
TOTAL	86	60	31	52
GRAND TOTAL	308	188	84	[illegible]

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Air Reserve Officers'
Training Corps Enrollment Data
15 Feb 1950

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AIR RESERVE OFFICERS' TRAINING CORPS ENROLLMENT DATA

BY AIR FORCE

(Including White and Negro Personnel)

As of 15 February 1950

AIR FORCE	NO. OF INSTITUTIONS	STUDENTS FORMALLY ENROLLED — ELEMENTARY 1st Yr	ELEMENTARY 2nd Yr	ADVANCED 1st Yr	ADVANCED 2nd Yr
First Air Force	19	2311	1797	809	538
Fourth Air Force	19	3108	1873	824	786
Ninth Air Force	22	4420	3530	1231	839
Tenth Air Force	32	5201	3325	1493	1371
Twelfth Air Force	16	1957	1652	1268	806
Fourteenth Air Force	18	2073	1595	1065	702
TOTAL	126	19070	13772	6630	5042

NOTE: Detailed Listing of ROTC Institutions and Enrollment Data on following pages.

SOURCE: (RCS AF-SC-P162)

PREPARED BY:
Headquarters, Continental Air Command,
Office of Statistical Services.

2-3312-2

Incl #2

REPORT OF AIR ROTC STUDENTS

As of 15 February 1950

TRAINING DATA

AIR ROTC Training	Students Formally Enrolled	Other Students
	WHITE	
1st Year Basic	18754	39
2nd Year Basic	13564	24
1st Year Advanced	6514	160
2nd Year Advanced by course title		
Administration & Supply	2724	
Aircraft Maintenance Engineering	793	
Armament	131	
Communications	157	
Comptrollership	362	
Air Installations	460	
Transportation	330	
Total 2nd Year Advanced	4957	28
TOTAL WHITE	43789	191
	NEGRO	
1st Year Basic	316	
2nd Year Basic	208	
1st Year Advanced	116	6
2nd Year Advanced by course title		
Administration and Supply	29	
Aircraft Maintenance	1	
Communications	3	
Comptrollership	3	
Transporation	49	
Total 2nd Year Advanced	85	—
TOTAL NEGRO	725	6

REPORT OF AIR ROTC STUDENTS

As of 15 February 1950

COMMUTATION SUBSISTENCE AND UNIFORM DATA

	Total	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
			WHITE		
1. Receiving Commutation Subsistence	11467			6511	4956
2. Receiving Commutation Uniforms	8157	1159	831	3609	2558
3. Drawing Issue Uniforms	35627	17595	12728	2905	2399
4. Drawing Neither Commutation Nor Issue Uniforms	5		5		
			NEGRO		
1. Receiving Commutation Subsistence	201			116	85
2. Receiving Commutation Uniforms	33		1	17	15
3. Drawing Issue Uniforms	692	316	207	99	70
4. Drawing Neither Commutation Nor Issue Uniforms					

REPORT OF AIR ROTC STUDENTS

As of 15 February 1950

SCHOOL SUMMARY

	Students Formally Enrolled			
	1st Year Basic	2nd year Basic	1st Year Advanced	2nd Year Advanced
		WHITE		
First Air Force				
Union College	55		7	
Newark College of Engineering	56		33	
Boston University	117	116	67	35
Colgate University	21	77	25	17
University of Connecticut	364	205	50	47
Cornell University	372	184	65	41
Fordham University	104	97	69	49
Harvard University	26	41	18	23
University of Massachusetts	169	97	50	45
Massachusetts Institute of Tech	121	126	34	50
University of New Hampshire	228	131	81	42
New York University	142	201	41	34
Rutgers University	218	209	49	41
Syracuse University	60	81	83	45
Trinity College	51	74	8	13
Williams College	33	44	20	19
Yale University	40	106	37	36
Rensselaer Polytechnic Institute	50		41	
Stevens Institute of Technology	74		29	
TOTAL	2301	1789	807	537
Fourth Air Force				
Oregon State Col	273	176	40	43
Stanford University	15	45	34	26
University of Oregon	243	148	28	32
University of Arizona	212	140	63	44
San Jose State College	30	33	43	40
State College of Washington	266	139	56	63
University of Utah	42	62	65	61
University of Calif.(Los Angeles)	444	258	39	38
Montana State University	198	68	22	23
Montana State College	127	88	27	19
Loyola University of Los Angeles	174	100	46	26
University of Washington	337	222	37	66
Arizona State College	205	110	20	13
University of Southern California	7	29	46	45
University of Nevada				32
Utah State Agricultural College	309	97	186	154
Fresno State College	11	18	17	17
University of Idaho	166	135	45	43
Montana School of Mines	36		10	
TOTAL	3095	1868	824	785

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REPORT OF AIR ROTC STUDENTS

As of 15 February 1950

SCHOOL SUMMARY

	Students Formally Enrolled			
	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
Ninth Air Force		WHITE		
University of Louisville	40	44		
Miami University	51		34	
Western Kentucky State College	98	68	52	12
University of Kentucky	283	235	115	82
University of Cincinnati	108	149	59	76
Ohio State University	850	516	87	65
Ohio University	340	192	89	36
Lehigh University	292	186	33	29
The Penn State College	451	362	101	57
Virginia Polytechnic Institute	149	131	64	66
West Virginia University	172	150	60	47
University of Maryland	775	747	122	31
Gettysburg College	56	63	28	13
University of Pennsylvania	25	82	48	36
Duquesne University	162	141	72	42
Johns Hopkins University	35	28	8	20
University of Pittsburgh	92	106	61	57
University of Akron	129	102	42	33
Georgetown University	39	65	35	35
Virginia Military Institute	88	62	62	68
Ohio Wesleyan University	24		15	
TOTAL	4259	3429	1187	805
Tenth Air Force				
University of Illinois	252	178	33	26
Coe College	81	46	22	23
Iowa State College of A&MA	338	237	58	55
State University of Iowa	240	179	55	53
University of Minnesota	84	98	85	82
University of Wisconsin	238	204	53	38
University of Missouri	354	188	79	69
St Louis University	148	159	115	164
Kansas State College of A&AS	337	190	55	53
Municipal University of Wichita	67	44	37	33
University of Kansas	30	61	77	48
University of Nebraska	207	123	46	44
Colorado State College of AMA Arts	471	165	48	53
University of Denver	10		26	54
University of Wyoming	44	21	7	16
North Dakota Agricultural College	167	95	32	27
University of North Dakota	89	32	16	28
South Dakota State College of A&MA	88	32	13	27

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REPORT OF AIR ROTC STUDENTS

As of 15 February 1950

SCHOOL SUMMARY

	Students Formally Enrolled			
	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
		WHITE		
Tenth Air Force Cont'd				
College of St Thomas	264	191	99	57
Superior State College	142	40	16	18
Bradley University	100	60	44	24
Washburn Municipal University	25	24	11	19
University of Notre Dame	46	56	34	26
Purdue University	217	147	52	42
Indiana University	475	261	98	40
Ball State Teachers College	49	49	14	23
Butler University	61	31	51	22
University of Michigan	29	18	24	36
Michigan State College of A & AS	404	247	93	85
Michigan College of M&T	55	54	26	46
Wayne University	29	57	24	31
University of Detroit	43	13	39	
TOTAL	5184	3320	1482	1362
Twelfth Air Force				
University of Arkansas	134	114	87	43
New Mexico College of A & MA	91	59	46	32
Oklahoma A&M College	375	212	78	59
University of Oklahoma	246	215	106	73
Agricultural & Mechanical College of Texas	512	329	229	203
Texas Technological College	42	85	60	53
University of Texas	46	78	120	88
Louisiana State University	112	212	80	69
Tulane University	27	54	39	31
Southwestern La. Institute	38	82	47	46
Southern Methodist University	12	49	107	77
Baylor University	71	90	60	30
Louisiana Polytechnic Institute	44	30	19	
University of New Mexico	36		38	
University of Tulsa	36	13	47	2
E Texas Teachers College	135	30	45	
TOTAL	1957	1652	1208	806

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REPORT OF AIR ROTC STUDENTS

As of 15 February 1950

SCHOOL SUMMARY

	Students Formally Enrolled			
	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
	WHITE			
Fourteenth Air Force				
Alabama Polytechnic Institute	173	136	57	37
University of Alabama	232	279	119	76
The Citadel	65	72	72	54
Clemson Agricultural College	175	55	59	58
Georgia Institute of Technology	140	115	82	55
University of Georgia	102	49	63	44
Mississippi State College	129	98	63	64
University of Mississippi	40	78	42	30
University of Florida	393	263	88	74
University of Miami	50	91	105	34
North Carolina State College of A&E	133	114	58	33
East Carolina Teachers College	41	17	27	29
University of North Carolina	60	64	73	53
University of Tennessee	45	33	15	20
Duke University	64			
Florida State University	46	12	41	1
University of South Carolina	70	30	42	
TOTAL	1958	1506	1006	662
GRAND TOTAL	18754	13564	6514	4957

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REPORT OF AIR ROTC STUDENTS

As of 15 February 1950

SCHOOL SUMMARY

	Students Formally Enrolled			
	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
		NEGRO		
First Air Force				
Yale		1		
Fordham		1	1	
Massachusetts Institute of Tech.			1	
New York University	3	2		1
Williams College	1			
University of Connecticut	3			
Boston University		4		
Syracuse University	3			
TOTAL	10	8	2	1
Fourth Air Force				
Loyola University of Los Angeles	4	1		
Arizona State College	5	3		
Fresno State		1		1
University of Oregon	4			
University of Arizona				
TOTAL	13	5	—	1
Ninth Air Force				
University of Cincinnati	3	2	1	
Ohio State University	32	9		2
Howard University	121	85	39	29
University of Pennsylvania			1	1
Duquesne University	2	1		
University of Pittsburgh	1	2	3	2
Pennsylvania State College	2	2		
TOTAL	161	101	44	34
Tenth Air Force				
Municipal University of Wichita	3		1	
University of Illinois	5		2	
University of Iowa				
St Louis University		1	1	3
University of Kansas			1	1
Colorado State College A&M Arts		1		
Washburn Municipal University	4			
University of Michigan	1	1	1	
Michigan State College of A&AS				2
Wayne University	1	1	3	3
University of Minnesota			1	
Purdue University				
Butler University	3	1	1	
TOTAL	17	5	11	9

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REPORT OF AIR ROTC STUDENTS

As of 15 February 1950

SCHOOL SUMMARY

	Students Formally Enrolled			
	1st Year Basic	2nd Year Basic	1st Year Advanced	2nd Year Advanced
		NEGRO		
Fourteenth Air Force				
Tuskegee University	115	89	59	40
TOTAL	115	89	59	40
GRAND TOTAL	316	208	116	65

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AIR FORCE ROTC

TRAINING EVALUATION REPORT

ACADEMIC YEAR 1948–1949

HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK

HEADQUARTERS
CONTINENTAL AIR COMMAND
Mitchel Air Force Base, New York

ROTC 334 20 September 1949

SUBJECT: Results of the 1949 Air Force ROTC Evaluation Program

TO : Commanding Generals', Continental Air Command Air Forces

1. Transmitted herewith are the results of the examinations given to Air Force ROTC cadets during the Academic Year 1948-1949 in the following areas:

a. ROTC Qualifying Examination, RQ-3-49-First Year Basic Students.
b. Introduction to USAF - First Year Advanced.
c. Administration and Military Management- Second Year Advanced.
d. Aircraft Maintenance Engineering- Second Year Advanced.
e. Air Force Armament- Second Year Advanced.
f. Air Force Communications - Second Year Advanced.
g. Statistical Control - Second Year Advanced.
h. Air Force Supply - Second Year Advanced.
i. Air Force Transportation - Second Year Advanced.

2. Air Force Commanders, Professors of Air Science and Tactics, Instructors and Assistant Instructors will examine this report and where necessary take corrective action and/or recognize superior performance with a view toward improving AFROTC training.

3. The major purposes of this and future evaluation reports is to reveal areas where proper performance levels are being maintained, to indicate the directions in which improvements should be made, and to afford essential facts for self directed development on the part of the instructor. It is the latter purpose which is the most important of all since its effective realization on the part of each instructor will influence the growth and development of future Air Force officers.

4. The preparation and administration of these examinations were accomplished through the cooperative efforts of all personnel involved in the AFROTC program. It is felt that through continued cooperative efforts the level of instruction will be improved and more effective evaluation techniques developed.

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5. This report will be brought to the attention of interested University officials, that is members of the civilian instructional staff interested in educational evaluation, the military coordinator, and each member of the AFROTC staff. Suggestions as to means by which future evaluation procedures and reports can be more helpful are solicited.

BY COMMAND OF MAJOR GENERAL WEBSTER:

J. H. BLOSS
Lt Col., AGD (USAF)
Asst Adj Gen

1 Incl
Results of Air ROTC Examination

Cys Furnished:

10- Chief of Staff, USAF
5- Chief, Army Field Forces
5- Chief, Naval Operations
5- CG Air Training Command
5- CG Air University
5- CG Air Materiel Command
10- CG's ConAC Air Forces
3- Each AFROTC unit

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CHAPTER I

THE ROLE AND USES OF AIR-FORCE-WIDE COURSE EXAMINATIONS IN THE AIR ROTC PROGRAM

The Prime Mission

The elemental fact is that air-force-wide course examinations are directly and closely releated to the prime question, Are our Air Force ROTC schools achieving the objectives that they are supposed to reach? This major responsibility rests upon the shoulders of every instructor and every supervisor and they should be able to answer this question -- the teacher for his class -- and the supervisor for his school. In order to answer this question, it is necessary to assemble all the essential information and evaluate these facts with reference to the attainment of the goals of Air Force ROTC schools. This evaluation process is many-sided, continuous, and should include both subjective and objective ratings or measures. In this board evaluation process, testing through the use of achievement examinations occupies a coordinate and significant role, namely that of providing objective, valid and systematic evidence of the degree to which students are developing the facts, knowledges and understandings which should be the outcomes of coordinated and integrated instruction periods.

The air-force-wide achievement or course examinations are valid, reliable, and objective measuring instruments. These examinations have been designed for the purpose of revealing the student's general level of accomplishment and his proficiencies and deficiencies in his field of specialization, and for the purpose of providing the director and officer instructor a factual basis in terms of objective

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test results for changes in personnel, procedures and policies.

The evaluation of student achievement is not the task of any one person. The director, the Professor of Air Science and Tactics, and the school instructors are all involved and though they participate in the evaluation program in different roles, they receive benefits from it. In subsequent paragraphs some of the specific uses of achievement or course examinations by the instructor, supervisor and director will be listed. All members of the staff make use of the same basic data, but these data may be interpreted in different ways.

<u>How the Instructor Uses the Examination Results</u>

Fundamentally, effective instruction results largely from the contact of instructor and individual student, and therefore, the importance of the instructor's use of the tests is manifest. It is axiomatic that the more individualized the instruction, the better the quality and the greater the quantity of desired changes will be engendered in the student. This critical learning principle will yield sterile results unless the instructor knows the strength and weakness of the individual student and his class, and plans intelligently for his particular needs as far as is practical. Some of the ways in which the instructor may use test results and provide optimum conditions for the individualization of instruction are as follows:

1. To help determine the achievement level of each student in each course with relation to ability and experience.
2. To determine the average achievement level of a class at the end of the year.

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3. To compare present achievement with past achievement in order to determine the rate of progress.
4. To compare the achievement of his class with other classes and with the national or air-force-wide norm or standard.
5. To obtain a picture of the nature and range of individual differences in the group and make lesson plans with these considerations in mind.
6. To help diagnose an individual pupil's difficulties in learning.
7. To call attention to certain topics or sub-topics where more detailed testing is required to check on the effectiveness of instruction.
8. To provide a basis for counseling with the student's educational adviser regarding a pupil's achievement.
9. To provide one objective check on his own effectiveness.
10. To contribute an objective rating to the student's final course grade.
11. To serve as a motivating factor for the student.

These examinations can be used, therefore, to guide and motivate learning, to measure how much, how well, and how rapidly each student has progressed, to serve as a basis for the removal of individual difficulties, to help to evaluate the achievement of each student in terms of his ability and effort and to give the instructor one reading as to how well his instruction is received by his students.

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How the Professor of Air Science and Tactics Uses the Test Results

The Professor of Air Science and Tactics is also interested in the same kind of examination information as is the teacher. However, there are other aspects of the test which have particular interest for him as the administrative head of the school. Some of these other uses to which he may put the test results are as follows:

1. To determine the achievement level of each course group in a school.
2. To get an over-all picture of each course group in relation to each other course group.
3. To discover course specialization fields where test results are excellent, satisfactory, or poor.
4. To compare course test results from year to year and note improvement or regression.
5. To provide a continuing record of achievement in the school which will reflect changes in course content emphasis and in the characteristics of the student population,
6. To provide objective information on a student's avhievement for various administrative purposes.
7. To provide a basis for working with an individual instructor on methods of teaching and content of the course.

How The Administrative Personnel Uses the Test Results

1. To determine the achievement status of each school in each course in comparison with a national norm or average.
2. To evaluate the comparative achievements from course to course.

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3. To compare present achievement with past achievement in order to determine the rate of progress.
4. To compare the achievement of his class with other classes and with the national or air-force-wide norm or standard.
5. To obtain a picture of the nature and range of individual differences in the group and make lesson plans with these considerations in mind.
6. To help diagnose an individual pupil's difficulties in learning.
7. To call attention to certain topics or sub-topics where more detailed testing is required to check on the effectiveness of instruction.
8. To provide a basis for counseling with the student's educational adviser regarding a pupil's achievement.
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How The Administrative Personnel Uses the Test Results

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2. To evaluate the comparative achievements from course to course.

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3. To evaluate the comparative achievement from school to school in specified courses and with particular reference to administrative considerations such as time allotments, student load, quality and quantity of instructional materials, and particular school's policy and practice regarding Air Force ROTC courses.

4. To detect changes in the character of the student population over a period of years.

5. To determine those course fields in which further professional training of instructors is desirable.

6. To evaluate teaching and instructional materials.

7. To direct and control significant broad curricular emphasis.

8. To determine the possible need for curriculum changes.

9. To determine the minimum levels of achievement in specified specialization fields.

10. To provide an air-force-wide yardstick necessary for adequate and valid evaluations and comparisons.

The uses of examinations as listed above do not exhaust all the possibilities. Other uses could be listed.

An air-force-wide program of evaluating student progress contributes to the coordination of the various educational activities of the schools; first, through cooperative efforts to agree on common objectives and emphasis. Clearly defined standards or goals in terms of examination questions, determined co-operatively by all who participate in evaluating student achievement, bring about good working relationships.

A basic requirement in evaluation namely, that objectives be clearly defined, stated and eventually incorporated into significant thought-provoking examination questions helps the instructors to know what they are trying to appraise, what experiences to provide for students, and what evidence of growth they must look for in students.

In conclusion, therefore, the examination can be, and often is, an extremely important instrument. Every examination teaches both the instructor and student something. The examination affects their mental processes and attitudes.

Insofar as is humanly possible, the examination should be constructed not to train the students in memory processes only. On the other hand, questions should be phrased so that students are directed to relate facts, apply them to meaningful problems, develop principles and generalizations. Investigations show that the method of student preparation does differ with the characteristics of an examination. On the other hand, the results of studies also show that a method of studying which emphasized organization of material resulted in a better command of the subject as tested by four different types of examinations. Instead of emphasizing methods of storing up prospective answers for examinations, the students should be given practice in organizing, relating, and evaluating. In other words, instead of causing the thinking process to be narrowly confined, questions and examinations should stimulate critical thinking, get at understandings and fundamental concepts. If the instructor is willing to devise questions for examinations so that they stress judgment, evaluation, and original reactions many can succeed in so doing.

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CHAPTER II

ACHIEVEMENT OF AIR ROTC SCHOOLS ON THE ANNUAL COURSE EXAMINATIONS

The Air ROTC course examinations were administered to 8092 students in 112 colleges and universities throughout the United States. In all, there were eight course examinations utilized. Each course examination was composed of eighty (80) multiple choice (five alternatives) items covering the significant areas in the following course fields:

1. Administration and Military Management.
2. Aircraft Maintenance Engineering.
3. Armament.
4. Communications.
5. Introduction to USAF.
6. Statistical Control.
7. Supply.
8. Transportation.

These course examinations are achievement tests which cover the important facts, knowledges and understandings in each of the eight Air ROTC courses or job fields.

The number of schools taking each examination varied. The greatest number, 112 schools, took the Introduction to USAF examination; the smallest number of schools, seven (7), took the Armament examination.

All test scores were recomputed according to the formula:

> Test score equals the number of correct responses minus one-fourth (1/4) the number of wrong responses.

The results of each of the eight examinations reveal a wide range of student achievement as shown in the summary of the lowest and highest scores for each examination. The latter results and additional data are given below:

1949 Air ROTC Course Examination	Students Examined	No. of Schools	Lowest Score	Average Score	Highest Score	No. of Items
Administration & Military Management	1379	55	14	49	76	80
Aircraft Maintenance	497	30	21	55	78	80
Armament	154	7	13	53	76	80
Communications	225	19	10	52	80	80
Introduction to USAF	5043	112	0	49	79	80
Statistical Control	269	15	26	51	69	80
Supply	306	18	22	52	76	80
Transportation	219	12	23	48	78	80

The greatest range, from zero score to a score of 79, was that for the examination, Introduction to USAF. The examination with the smallest range is that for Statistical Control. In general, the test that can distribute the examinees over the wider range is the better test.

The mean or average scores of the eight tests range from 48 to 55. The Aircraft Maintenance examination with a mean score of 55, and the Transportation examination with a mean score of 48, were the highest and lowest means respectively. The mean scores on the examinations ranged from 48 to 55 and may indicate that the tests were not of equal difficulty. However, it is hazardous to make any conclusions as to the difficulty of the tests unless at least the mean mental ability of the various examination groups were approximately equal. No definite information on the latter point is available at present.

An analysis of the test results of the various schools was planned. A distribution of mean scores of all schools taking a specific examination was made. Table 1 presents the latter test results for all course examinations. The greatest number of schools taking a course examination was 112 (Introduction to USAF). The range of achievement on each of the examinations is very wide. For example, on the Transportation examination, one school of the twelve (12) which took the examination attained a mean score in the interval 72-74, while two of the twelve schools attained a mean score of 30. The range of achievement on the Statistical Control examination was the smallest, namely, mean scores from 36 to about 53.

TABLE 1

COMPOSITE DISTRIBUTION OF SCHOOL MEAN SCORES ON AIR ROTC COURSE EXAMINATIONS
1948-1949

No. of Items on Test	80	80	80	80	80	80	80	80
(School Mean (Score Interval	Intro. to USAF	Admr.& Mil.Mng.	A/C Main.	Armament	Comms.	Stat.Con.	Supply	Trans.
72-74			1		1			1
69-71			1		1			0
66-68	1	3	2	2	0			1
63-65	3	3	3	1	1		1	1
60-62	4	5	0	1	0		0	0
57-59	8	3	6	0	2	1	4	0
54-56	13	6	4	0	2	3	4	0
51-53	14	5	3	1	4	6	1	0
48-50	17	6	5	0	1	2	2	0
45-47	18	9	2	0	2	1	1	2
42-44	23	8	2	0	1	1	4	2
39-41	5	2	0	1	2	0	1	1
36-38	5	3	0	0	2	1	0	2
33-35	0	2	1	0	0	0	0	0
30-32	1	0	0	0	0	0	0	2
27-29	0	0	0	1	0	0	0	0
Totals	112	55	30	7	19	15	18	12

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The variability in the achievement of the various schools on each examination may be simply, though not too accurately, measured by comparing the schools with the lowest means and the schools with the highest means. In some cases, the schools with the lowest means achieved roughly on the average only half as much as the schools which returned the highest averages.

The crude quotients of the division of lowest school means by the highest school means for each of the eight examinations reveal the following results:

1. Administration and Military Management. The schools with the lowest means achieved roughly on the average only half as much as the schools which returned the highest averages.

2. Aircraft Maintenance Engineering. The schools with the lowest means achieved roughly on the average only half as much as the schools which returned the highest averages.

3. Armament. The school with the lowest average achieved roughly about forty percent as much as the schools with the highest averages.

4. Communications. The schools with the lowest means achieved roughly only half as much as the schools which returned the highest averages.

5. Introduction to USAF. The schools with the lowest means achieved roughly only half as much as the schools which returned the highest averages.

6. Statistical Control. The schools with the lowest means achieved roughly about 66 percent as much as the schools with the highest averages.

7. Supply. The schools with the lowest means achieved on a average about 66 percent as much as the schools which returned the highest averages.

8. Transportation. The schools with the lowest averages achieved roughly on the average about 45 percent as much as the schools which returned the highest averages.

A more detailed analysis of the test results for each of the eight (8) examinations is given in the immediate subsequent sections of this chapter.

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RESULTS ON AIR ROTC COURSE EXAMINATIONS - 1949

Results of Administration and Military Management Examination

The 80-item test on Administration and Military Management was administered to 1,379 students. The results by air force and for all air forces combined are given in Table 2.

TABLE 2

Results of Administration and Military Management Examination for 55 Schools

Air ROTC 1948 - 1949

	No. of Students	Mean	Raw Score Lowest	Raw Score Highest	Relative Rank of Air Force
First Air Force	171	56	23	76	1
Fourth Air Force	217	54	25	76	2
Ninth Air Force	257	50	20	73	4
Tenth Air Force	303	53	21	75	3
Twelfth Air Force	218	44	14	68	6
Fourteenth Air Force	213	45	16	68	5
All Air Forces	1,379	49	14	76	

The First Air Force, with an average score of 56, achieved the top rank.

A distribution was made of the mean scores of the 55 schools where the test was given. This distribution of scores is given below in Table 3.

TABLE 3

Distribution of School Averages and Selected Percentiles On the Administration and Military Management Examinations

Distribution of Averages

School Average Score	No. of Schools
66-68	3
63-65	3
60-62	5
57-59	3
54-56	6
51-53	5
48-50	6
45-47	9
42-44	8
39-41	2
36-38	3
33-35	2
TOTAL	55

Score Value of Percentiles

Average Score	Percentile
68	99%
62	90%
57	80%
54	70%
51	60%
48	50%
46	40%
44	30%
42	20%
38	10%
33	1%

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The left half part of Table 3 shows that the school average scores range from a low of 33 to a high of 68. Of the 55 schools 37 or about 68% attained mean scores between 42 and 59. The schools with the lowest means achieved roughly on the average only half as much as the schools which returned the highest averages. There is evidently a very wide range in achievement among these schools.

As an aid in interpreting the school test results the distribution of school averages has been divided into percentiles. Percentiles are points in a distribution of scores below which lie a given percentage of the total number of schools. Eleven percentile points, P99, P90, P80, P70, P60, P50, P40, P30, P10 and P1 with their corresponding score values are given in the right hand part of Table 3. A school average of 68 was obtained by the top 1% of the 55 schools or stated in other words, 99% of the schools attained average scores below 68. An average score of 62 is the score at or below which lie 90% of the school averages; an average score of 57 is the score at or below which lie 80% of the school averages; an average score of 54 is the score at or below which lie 70% of the school averages. The other percentiles may be interpreted in a similar manner. P50 or the fiftieth percentile marks the mid-point of the distribution of school means, that is, it is the point below which fifty percent (50%) of the school averages lie and above which the other fifty percent (50%) lie. The great majority of the schools attained mean scores between thirty percentile points above P50, i.e., P80 and thirty percentile points below P50, e.e., P20. The range P20 to P80 includes the middle 60% of the school averages or stated in terms of score values the middle 60% of the school averages fell between 42 and 57. Schools attaining averages in the bottom 30%, i.e., P30, may find it highly desirable to institute changes in methods of instruction, to heighten student interest, and to provide adequate curricular materials. However in evaluating the achievement of the latter group of schools it is necessary to take into consideration the mental ability of the students concerned. See Chapter 6 for a better explanation.

Table 4 gives the mean scores and percentiles for each of the schools which took the examination in Administration and Military Management.

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TABLE 4

Means and Percentile Ranks of Air ROTC Schools Which Took Administration and Military Management Examination

AIR ROTC 1948-49

Schools	No. of Students Examined	RAW SCORE (Possible 80) Mean	Lowest	Highest	*Percentile Rank of 30 Schools
ALL AIR FORCES	1379	49	14	76	
FIRST AIR FORCE	171	56	23	76	
Yale University	22	61	38	74	89
Boston University	16	46	23	66	40
Univ.of New Hampshire	17	48	41	66	50
Rutgers University	8	42	39	46	20
Colgate University	14	43	31	51	25
Fordham University	41	57	41	74	80
New York University	29	66	55	76	97
Syracuse University	24	61	52	70	88
FOURTH AIR FORCE	217	56	25	76	
Arizona State College	1	36	36	36	7
San Jose State College	35	45	25	55	35
University of Idaho	29	64	53	75	94
University of Nevada	7	41	29	49	19
University of Oregon	17	47	32	59	45
Utah State Agri.College	53	67	58	76	97
University of Utah	34	51	36	64	60
University of Washington	41	45	30	64	35
NINTH AIR FORCE	257	50	20	73	
Univ. of Kentucky	39	38	20	57	10
West Kentuck State Tchrs	7	47	37	56	45
Johns Hopkins Univ	7	53	44	64	67
University of Akron	13	68	63	71	99
Univ of Cincinnati	47	52	38	67	63
Duquesne University	29	42	28	61	20
Penn State College	11	55	43	69	73
Univ of Pennsylvania	15	51	31	66	60
Univ of Pittsburgh	40	50	32	65	57
Virginia Mil. Inst.	15	56	42	72	77
Virginia Polytechnic Inst.	10	45	40	55	35
West Virginia University	24	63	36	73	92

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TABLE 4 - Adm & Mil Mngmt Exam (Continued)

AIR ROTC 1948-49

Schools	No. of Students Examined	RAW SCORE (Possible 80)			*Percentile Rank of 30 Schools
		Mean	Lowest	Highest	
TENTH AIR FORCE	303	53	21	75	
Univ. of Denver	29	55	33	67	73
Univ. of Illinois	11	48	36	57	50
Indiana University	29	61	45	75	88
Univ. of Notre Dame	20	40	21	55	16
State Univ. of Iowa	16	60	50	68	86
Kansas State College	20	59	46	73	84
Univ. of Kansas	53	50	35	69	57
Univ. of Wichita	19	50	31	60	57
Univ. of Missouri	27	57	48	67	80
Univ. of Nebraska	19	64	51	73	94
N.Dakota Agri. College	10	43	33	48	25
Univ. of North Dakota	7	45	38	54	35
Univ. of Wyoming	8	43	25	52	25
Michigan State Coll. of A&S	22	33	21	60	1
Univ. of Michigan	13	60	52	69	86
TWELFTH AIR FORCE	218	44	14	68	
Louisiana State Univ.	22	56	33	68	77
Tulane University	24	43	14	67	25
Oklahoma A&M	31	48	36	66	50
A&M College of Texas	60	34	15	56	3
Texas Tech College	27	54	34	69	70
Univ of Texas	54	46	24	61	40
FOURTEENTH AIR FORCE	213	45	16	68	
Univ. of Alabama	53	42	23	65	20
Univ. of Florida	44	54	36	66	70
Georgia Inst. of Tech.	12	53	44	61	67
Univ. of Georgia	38	45	30	66	35
Miss. State College	53	44	16	68	30
Univ. of Mississippi	13	36	22	49	7

* Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of fifty (P50) means that the school attained a score below which approximately fifty per cent of the school mean scores lie and above which the other fifty per cent lie. A percentile rank of ninety (P90) indicates that approximately ninety per cent of the schools attained mean scores below this point, and that only ten per cent of the schools achieved scores above this point. Therefore, the 99th percentile is the highest or best percentile ranking and the 1st percentile is the lowest or poorest percentile ranking.

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Results of Aircraft Maintenance Engineering Examination

The 80-item test on Aircraft Maintenance Engineering was administered to 497 students. The results by air force and for all air forces combines are given in Table 5.

TABLE 5

Results of Aircraft Maintenance Engineering Examination for 30 Schools

Air ROTC 1948 - 1949

Air Force	No. of Students	Mean	Lowest	Highest	Relative Rank of Air Force
First Air Force	10	45	24	65	6
Fourth Air Force	89	50	21	72	4
Ninth Air Force	88	62	39	78	2
Tenth Air Force	126	54	27	74	3
Twelfth Air Force	113	48	23	74	3
Fourteenth Air Force	71	63	31	76	1
All Air Forces	497	55	21	78	

The Fourteenth Air Force, with an average score of 63, achieved the top rank.

A distribution was made of the mean scores of the 30 schools where the test was given. This distribution of scores is given below in Table 6.

TABLE 6

Distribution of School Averages and Selected Percentiles on the Aircraft Maintenance Engineering Examination

Distribution of Averages: School Average Scores	No.	Score Value of Percentiles: Average Score	Percentile
72-74	1	73	99%
69-71	1	69	90%
66-68	2		
63-65	3	64	80%
60-62	0		
57-59	6	59	70%
		57	60%
54-56	4	55	50%
51-53	3	53	40%
48-50	5	50	30%
45-47	2	47	20%
42-44	2	44	10%
39-41	0		
36-38	0		
33-35	1	33	1%
Total	30		

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The left half part of Table 6 shows that the school averages range from a low of 33 to a high of 74. Of the 30 schools 23 or about 77% attained means scores between 45 to 65. The schools with the lowest means achieved roughly on the average only half as much as the schools which returned the highest averages. Even though the number of participating schools are as few as thirty, nevertheless there is evidence of a great variation in achievement from school to school.

As an aid in interpreting the school test results the distribution of school averages has been divided into percentiles. Percentiles are points in a distribution of scores below which lie a given percentage of the total number of schools. Eleven percentile points, P99, P90, P80, P70, P60, P50, P40, P30, P20, P10 and P1 with their corresponding score values are given in the right hand side of Table 6. A school average of 73 was obtained by the top 1% of the 30 schools or stated in other words, 99% of the schools attained average scores below 73. An average score of 69 if the score at or below which lie 90% of the school averages; an average score of 64 is the score at or below which lie 80% of the school averages; an average score of 59 is the score at or below which lie 70% of the school averages. The other percentiles may be interpreted in a similar manner. P50 or the fiftieth percentile marks the mid-point of the distribution of school means, that is, it is the point below which 50% of the school averages like and above which the other fifty percent (50%) lie. The great majority of the schools attained mean scores between thirty percentile points below P50, i.e., P30, and thirty percentiles points below P50, i.e., P20. The range P20 to P80 includes the middle 60% of the school averages or stated in terms of score values the middle 60% of the school averages fell between 47 and 64. Schools attaining averages in the bottom 30%, i.e., P30, may find it highly desirable to institute changes in methods of instruction, to heighten student interest, and to provide adequate curricular materials. However in evaluating the achievement of the latter groups of schools it is necessary to take into consideration the mental ability of the students concerned. See Chapter 6 for a fuller explanation.

Table 7 gives the mean scores and percentiles for each of the schools which took the examination in Aircraft Maintenance.

TABLE 7
AIRCRAFT MAINTENANCE ENGINEERING EXAMINATION
Air ROTC 1948-1949

Schools	No. of Students Examined	RAW SCORE (Possible 80) Mean	Lowest	Highest	*Percentile Rank of 30 Schools
ALL AIR FORCES	497	55	21	78	
FIRST AIR FORCE	10	45	24	65	
Univ of New Hampshire	5	59	45	65	70
Rutgers University	5	33	24	42	1
FOURTH AIR FORCE	89	50	21	72	
Univ. of Arizona	19	47	30	71	20
Stanford Univ.	16	49	38	62	27
Univ. of So. Calif.	14	48	37	62	23
Univ. of Nevada	7	43	26	60	9
Univ. of Utah	17	55	21	72	50
Univ. of Washington	16	55	40	61	50
NINTH AIR FORCE	88	62	39	78	
Univ. of Kentucky	23	55	47	69	50
Univ. of Maryland	6	58	53	68	65
Ohio St. University	16	66	39	76	82
Penn St. College	15	73	64	78	99
Virginia Mil. Inst.	10	58	45	71	65
W. Virginia Univ.	18	63	49	69	69
TENTH AIR FORCE	126	54	27	74	
Colorado St. Col. A&M	16	51	38	70	33
Univ. of Denver	11	47	27	58	20
Univ. of Illinois	8	58	52	69	65
Purdue University	24	49	28	64	27
Kansas St. College	7	64	58	74	80
Univ. of Wisconsin	12	58	45	67	65
Michigan Coll. of M&T	24	53	32	66	40
Michigan St. Coll. of A&S	24	59	44	68	70
TWELFTH AIR FORCE	113	48	23	74	
La. St. Univ.	18	49	39	74	27
Oklahoma A&M	14	48	33	61	23
Univ. of Oklahoma	23	53	31	67	40
A & M College of Texas	58	43	23	63	9
FOURTEENTH AIR FORCE	71	63	31	76	
Alabama Poly. Inst.	27	64	54	72	80
Ga. Inst. of Tech.	15	67	57	76	84
N.Car. St. Coll A&E	9	70	60	76	92
Clemson Ag. Coll.	20	55	31	71	50

*Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A Percentile rank of fifty (P50) means that the school attained a score below which approximately fifty (P50) percent of the school mean scores lie and above which the other fifty percent lie. A percentile rank of ninety (P90) indicates that approximately ninety percent of the schools attained mean scores below this point, and that only ten percent of the schools achieved scores above this point. Therefore, the 99th percentile is the highest or best percentile ranking and the 1st percentile is the lowest or poorest percentile ranking.

Results of Armament Examination

The 80-item test on Armament was administered to 154 students in seven (7) schools. The mean score attained by these students from all participating air forces was 53. No comparison by separate air forces was made because the number of schools represented in each of the air forces were too few. However, adistribution of the mean scores of the seven (7) schools was made and the tabulation is given in Table 8.

TABLE 8

Distribution of School Averages and Estimated Percentiles on the Armament Examination for 7 Schools

Air ROTC 1948 - 1949

Distribution of Averages		*Estimated Score Values of Percentiles	
School Average Scores	No.of Schools	Average Score	Percentiles
66-68	2	68	99%
63-65	1	65	80%
60-62	1		
57-59	0		
54-56	0	56	50%
51-53	1		
48-50	0		
47-47	0		
42-44	0		
39-41	1	41	20%
36-38	0		
33-35	0		
30-32	0		
27-29	1	27	1%
TOTAL	7		

* Percentiles given here are very rough estimates.

The left half part of Table 8 shows that the school averages range from a low of 27 to a high of 68. The school with the lowest mean achieved roughly on the average about forty per cent (40%) as much as the schools which returned the highest averages. There is a wide variation in achievement from school to school. As an aid in interpreting the school test results the distribution of school averages has been divided into percentiles. Percentiles are points in a distribution of scores below which lie a given percentage of the total number of schools. Five percentile points, P99, P80, P50, P20 and P1 with their corresponding score values are given in the right-hand part of Table 8. These percentiles, because of the very few cases involved, are very rough estimates and have been interpolated so that certain inter-test comparisons can be made later. With this limitation in mind an explanation of the meaning of these percentiles will be given. A school average of 68 was achieved by the top 1 per cent of the 7 schools or stated in other words, 99 per cent of the schools attained average scores below 68. An average score of 65 is estimated to be the score at or below which lie 80 per cent of the school averages. P50, i.e., the fiftieth percentile roughly marks the mid-point of the distribution of school means, that is, it is the point below which roughly fifty per cent (50%) of the school averages lie and above which the other fifty per cent (50%) of the school averages lie and above which the other fifty percent (50%) lie. An average score of 41 is the score at or below which lie 20 per cent of the school averages, an average score of 27 is the score at or below which lie 1 per cent of the school averages. Schools attaining average scores in the bottom thirty per cent, i.e., P30 or average scores below 44 may find it highly desirable to institute changes in methods of instruction, to heighten student interest, and to provide adequate curricular material. However, in evaluating the achievement of the latter group of schools it is necessary to take into consideration the mental ability of the students concerned. See Chapter 6 for a fuller explanation.

Table 9 gives the mean scores and percentiles for each of the schools which took the examination in Armament.

TABLE 9

Means and Percentile Ranks of Seven Air ROTC Schools Which Took The Armament Examination

Air ROTC 1948-49

Schools	No. of Students Examined	RAW SCORE (Possible 80) Mean	Lowest	Highest	*Percentile Rank of 7 Schools
ALL AIR FORCES	154	53	13	76	
FOURTH AIR FORCE	28				
Utah St Agri College	28	68	51	75	99
NINTH AIR FORCE	23				
Georgetown University	23	28	13	43	1
TENTH AIR FORCE	43	59	41	76	
University of Kansas	20	51	41	71	40
University of Missouri	23	67	49	76	93

TABLE 9 - Armament Exam (Continued)

Schools	No. of Students Examined	RAW SCORE (Possible 80) Mean	Lowest	Highest	*Percentile Rank of 7 Schools
TWELFTH AIR FORCE	26				
Texas Tech College	26	40	24	54	19
FOURTEENTH AIR FORCE	34	61	49	72	
Mississippi State College	25	60	49	68	68
University of Tennessee	9	64	53	72	77

* Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of fifty (P50) means that the school attained a score below which approximately fifty percent of the school mean scores **lie** and above which the other fifty percent lie. A percentile of ninety (P90) indicates that approximately ninety percent of the schools attained mean scores below this point, and that only ten percent of the schools achieved scores above this point. Therefore, the 99th percentile is the highest or best percentile ranking and the 1st percentile is the lowest or poorest percentile ranking.

Because of the small number of schools involved, the percentile rankings are best estimated values.

Results of Communications Examination

The 80-item test on Communications was administered to 225 students. No comparison by air force was made because the number of schools represented in each air force were too few. However, a distribution of the mean scores of the 19 participating schools was made and the tabulation is given in Table 10.

TABLE 10

Distribution of School Averages and Selected Percentiles on the Communications Examination for 19 Schools

Air ROTC 1948-1949

Distribution of Averages: School Average Scores	No. of Schools	Score Value of Percentiles *: Average Score	Percentile
72-74	1	72	99%
69-71	1	69	90%
66-68	0		
63-65	1		

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TABLE 10 - Communications Exam (Continued)

Distribution of Averages		Score Value of Percentiles *	
School Average Scores	No. of Schools	Average Score	Percentile
60-62	0	61	80%
57-59	2	59	70%
54-56	2	54	60%
51-53	4	52	50%
48-50	1	49	40%
45-47	2	47	30%
42-44	1		
39-41	2	41	20%
36-38	2	38	10%
33-35	0	36	1%
Total	19		

* Percentiles given here are rough estimates.

The left half part of Table 10 shows that the school averages range from a low of 36 to a high of 74. Of the 19 schools 12 or 63% attained mean scores between 42 and 62. The schools with the lowest means achieved roughly on the average only half as much as the schools which returned the highest averages. There is evidently a very wide range in achievement among these schools.

As an aid in interpreting the school test results the distribution of school averages has been divided into percentiles. Percentiles are points in a distribution of scores below which lie a given percentage of the total number of schools. Eleven percentile points, P99, P90, P80, P70, P60, P50, P40, P30, P10 and P1 with their corresponding score values are given in the right hand part of Table 10. A school average of 72 was obtained by the top 1% of the 55 schools or stated in other words, 99% of the schools attained average scores below 72. An average score of 69 is the score at or below which lie 90% of the school averages; an average score of 61 is the score at or below which lie 80% of the school averages; an average score of 59 is the score at or below which lie 70% of the school averages. The other percentiles may be interpreted in a similar manner. P50, i.e., the fiftieth percentile marks the mid-point of the distribution of school means, that is, it is the point below which 50% of the school averages lie and above which the other 50% lie. The great majority of the schools attained mean scores between thirty percentile points above P50, i.e., P80 and thirty percentile points below P50, i.e., P20. The range P20 to P80 includes the middle 60% of the school averages or stated in terms of score values the middle 60% of the school averages fell between 41 and 61. Schools attaining averages in the bottom 30%, i.e., P30, may find it highly desirable to institute

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changes in methods of instruction, to heighten student interest, and to provide adequate curricular materials. However, in evaluating the achievement of the latter group of schools it is necessary to take into consideration the mental ability of the students concerned. See Chpater 6 for a fuller explanation.

Table 11 gives the mean scores and percentiles for each of the schools which took the examination in Communications.

TABLE 11

Means and Percentile Ranks of Air ROTC Schools Which Took the Communications Examination

Air ROTC 1948-49

Schools	No. of Students Examined	RAW SCORE (Possible 80) Mean	Lowest	Highest	*Percentile Rank of 19 Schools
ALL AIR FORCES	225	52	10	80	
FIRST AIR FORCE	25	47	10	68	
Massachusetts Inst of Technology	12	41	10	61	20
Cornell University	13	52	37	68	50
FOURTH AIR CORCE	57	55	27	80	
Univ of Cal at LA	11	37	27	57	1
Univ of Idaho	9	59	45	70	70
Montana State College	7	55	50	61	62
Oregon State College	12	47	34	70	30
Utah State Agr Coll	16	72	41	80	99
State Coll of Wash	2	64	61	66	83
NINTH AIR FORCE	29	43	25	65	
Johns Hopkins Univ	6	59	46	65	70
Lehigh University	17	39	25	58	13
Virginia Poly Inst	6	38	35	45	10
TENTH AIR FORCE	59	52	29	69	
Univ of Notre Dame	4	48	37	60	35
Iowa State College	15	53	33	69	55
Univ of Minnesota	32	53	33	69	55
Univ of Nebraska	8	47	29	58	30

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Table 11 - Communications Exam (Continued)

Schools	No. of Students Examined	RAW SCORE (Possible 80) Mean	Lowest	Highest	*Percentile Rank of 18 Schools
TWELFTH AIR FORCE	23	48	29	49	
Tulane University	12	52	38	69	50
Univ of Texas	11	44	29	52	25
FOURTEENTH AIR FORCE	32	62	43	76	
N.C. State College of A&E	15	54	43	66	60
Univ of Tennessee	17	69	50	76	90

* Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of fifty (P50) means that the school attained a score below which approximately fifty per cent of the school mean scores lie and above which the other fifty per cent lie. A percentile of ninety (P90) indicates that approximately ninety per cent of the schools attained mean scores below this point, and that only ten per cent of the schools achieved scores above this point. Therefore, the 99th percentile is the highest or best percentile ranking and the 1st percentile is the lowest or poorest percentile ranking.

Because of the small number of schools involved, the percentile rankings are best estimated values.

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Results of Introduction to USAF Examination

The 80-item test on the Introduction to USAF was administered to 5,043 students. The results by air force and for all air frces combined are given in Table 12.

TABLE 12

Results of Introduction to USAF Examination for 112 Schools Air ROTC 1948-1949

Air Force	No. of Students	Raw Score Mean	Raw Score Lowest	Raw Score Highest	Relative Rank of Air Forces
First Air Force	578	52	21	79	1
Fourth Air Force	806	49	0	75	3
Ninth Air Force	841	50	15	79	2
Tenth Air Force	1405	48	14	78	4.5
Twelfth Air Force	725	46	17	68	6
Fourteenth Air Force	687	48	4	75	4.5
All Air Forces	5043	49	0	79	

The First Air Force with an average score of 52 achieved the top rank.

A distribution was made of the mean scores of the 112 schools where the course examination was given. This distribution of scores is given below in Table 13:

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TABLE 13

Distribution of School Averages and Selected Percentiles on the Introduction to USAF Examination

Distribution of Averages		Score Value of Percentiles	
School Average Scores	No.	Average Score	Percentile
66-68	1	66	99%
63-65	3		
60-62	4		
57-59	8	57	90%
54-56	13	54	80%
51-53	14	52	70%
		50	60%
48-50	17	48	50%
45-47	18	46	40%
42-44	23	44	30%
		42	20%
39-41	5	41	10%
36-38	5		
33-35	0		
30-32	1	31	1%
Total	112		

The left half part of Table 13 shows that the school averages range from a low of 30 to a high of 68. Of the 112 schools 85 or about seventy-six percent (76%) attained mean scores between 42 and 56. The schools with the lowest means achieved roughly on the average only half as much as the schools which returned the highest averages. There is great variation in achievement among the schools, due principally to such factors as student ability and motivation, teacher personality, methods of instruction and adequacy of instructional materials.

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As an aid in interpreting the school test results the distribution of school averages has been divided into percentiles. Percentiles are points in a distribution of scores below which lie a given percentage of the total number of schools. Eleven percentile points, P99, P90, P80, P70, P60, P50, P40, P30, P20, P10 and P1 with their corresponding score values are given in the right hand part of Table 13. A school average of 66 was obtained by the top 1 percent of the 112 schools or stated in other words, 99% of the schools attained average scores below 66. An average score of 57 is the score at or below which lie 90% of the school averages; an average score of 54 is the score at or below which lie 80% of the school averages; an average score of 52 is the score at or below which lie 70% of the school averages. The other percentiles may be interpreted in a similar manner. P50, or the fiftieth percentile marks the mid-point of the distribution of school means, that is, it is the point below which fifty percent (50%) of the school averages lie and above which the other fifty percent (50%) lie. The great majority of the schools attained mean scores between thirty percentile points above P50, i.e., P80, and thirty percentile points below P50, i.e., P20. The range P20 to P80 includes the middle sixty per cent (60%) of the school averages or stated in terms of score values the middle sixty percent (60%) of the school averages fell between 44 to 54. Schools attaining averages in the bottom thirty per cent, i.e. P30, may find it highly desirable to institute changes in methods of instruction to heighten student interest, and to provide adequate curricular materials. However, in evaluating the achievement of the latter group of schools it is necessary to take into consideration the metal ability of the students concerned. See Chapter VI for a fuller explanation.

Table 14 gives the results on the Introduction to USAF examination.

TABLE 14

MEANS AND PERCENTILE RANKS OF AIR ROTC SCHOOLS
WHICH TOOK THE INTRODUCTION TO USAF EXAMINATION

AIR ROTC 1948-49

Schools	No. of Students Examined	RAW SCORE (Possible 80)			*Percentile Ranks of 112 Schools
		Mean	Lowest	Highest	
ALL AIR FORCES	5043	49	0	79	
FIRST AIR FORCE	578	52	21	79	
Trinity College	15	48	30	68	50
University of Conn.	47	59	41	75	92
Yale University	41	61	35	75	94
Boston University	36	53	36	73	75
Harvard University	29	48	29	66	50
Massachusetts Institute of Technology	46	42	22	60	42
Univ. of Massachusetts	40	51	31	69	65
Williams College	21	48	34	64	50
University of New Hampshire	45	52	21	71	70
Rutgers University	44	42	28	63	20
Colgate University	23	47	31	62	45
Cornell University	46	55	40	66	82
Fordham University	54	57	24	75	90
New York University	41	65	48	79	98
Syracuse University	50	50	30	69	60

*Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of fifty (P_{50}) means that the school attained a score below which approximately fifty per cent of the school mean scores lie and above which the other fifty per cent lie a percentile rank of ninety P_{90}) indicates that approximately ninety per cent of the schools attained mean scores below this point and that only ten per cent of the schools achieved scores above this point. Therefore, the 99th percentile is the highest or best percentile ranking and the 1st percentile is the lowest or poorest percentile ranking.

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INTRODUCTION TO USAF (continued)

Schools	No. of Students Examined	RAW SCORE (Possible 60) Mean	Lowest	Highest	*Percentile Ranks of 112 Schools
FOURTH AIR FORCE	806	49	0	75	
Arizona State College	14	47	33	60	45
University of Arizona	43	48	31	64	50
Fresno State College	21	40	14	50	9
Loyola University	27	54	34	67	80
San Jose StateCollege	45	48	33	69	50
Stanford University	24	57	43	66	90
Univ. of Calif. at LA.	36	48	28	67	50
Univ. of So. Calif.	50	51	28	68	65
Univ. of Idaho	54	62	44	74	95
Montana State College	22	54	37	68	80
Montana State University	26	55	29	73	82
Univ. of Nevada	32	38	20	58	7
Oregon State College	41	43	21	63	25
Univ. of Oregon	28	50	38	63	60
Utah St. Agri. College	148	46	30	68	40
Univ. of Utah	61	46	20	65	40
State College of Wash.	72	55	30	69	82
Univ. of Washington	62	47	0	75	45

*Percentile Ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of fifty (P_{50}) means that the school attained a score below which approximately fifty per cent of the school mean scores lie and above which the other fifty per cent lie a percentile rank of ninety (P_{90}) indicates that approximately ninety per cent of the schools attained mean scores below this point and that only ten per cent of the schools achieved scores above this point. Therefore, the 99th percentile is the highest or best percentile ranking and the 1st percentile is the lowest or poorest percentile ranking.

INTRODUCTION TO USAF (continued)

Schools	No. of Students Examined	RAW SCORE (Possible 80) Mean	Lowest	Highest	*Percentile Ranks of 112 Schools
NINTH AIR FORCE	841	50	15	79	
University of Kentucky	86	64	38	79	98
West Kentucky St. Tchrs.	14	44	30	65	30
Johns Hopkins Univ.	24	56	26	68	85
University of Maryland	36	42	25	66	20
Ohio St. Univ.	70	44	23	59	30
Ohio University	42	49	31	68	55
Univ. of Akron	37	52	23	76	70
University of Cincinnati	47	52	33	68	70
Duquesne University	48	42	20	68	20
Gettysburg College	15	59	47	69	92
Lehigh University	32	55	34	78	82
Penn St. College	59	45	25	64	35
Univ. of Penna.	38	54	39	66	80
Univ. of Pittsburgh	52	56	40	73	91
Virginia Military Inst.	63	61	36	78	94
Virginia Poly. Inst.	65	44	22	66	30
West Virginia Univ.	47	50	29	70	60
Georgetown Univ.	33	38	22	57	7
Howard University	33	31	15	51	1

*Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of fifty (P_{50}) means that the school attained a score below which approximately fifty per cent of the school mean scores lie and above which the other fifty per cent lie a percentile rank of ninety (P_{90}) indicates that approximately ninety per cent of the schools attained mean scores below this point and that only ten per cent of the schools achieved scores above this point. Therefore, the 99th percentile is the highest or best percentile ranking and the 1st percentile is the lowest or poorest percentile ranking.

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Schools	No. of Students Examined	Mean	RAW SCORE (Possible 80) Lowest	Highest	*Percentile Ranks of 112 Schools
TENTH AIR FORCE	1406	48	14	78	
Colorado State Coll. of A & M	57	42	15	60	20
University of Denver	59	50	30	67	60
Bradley University	26	47	19	65	45
Univ. of Illinois	26	56	45	67	85
Ball St. Tchrs. Coll.	27	46	30	66	40
Butler University	24	66	19	78	99
Indiana University	48	53	36	68	75
Purdue University	43	51	28	67	65
Univ. of Notre Dame	30	52	36	67	70
Coe College	30	47	30	66	45
Iowa St. College	57	45	25	63	35
St. Univ. of Iowa	59	42	22	59	20
Kansas St. College	54	59	48	74	92
Univ. of Kansas	48	53	43	65	75
Univ. of Wichita	36	63	28	78	86
Washburn Mun. Univ	22	45	25	60	35
Coll. of St. Thomas	67	45	23	68	35
Univ. of Minnesota	66	51	30	75	65
Univ. of Minnesota (Duluth)	21	36	24	51	5
St. Louis Univ.	76	43	27	61	25
Parks College	50	58	45	69	91
Univ. of Missouri	67	49	28	66	55
Univ. of Nebraska	45	52	39	70	70
No. Dakota Agric. Coll.	24	42	31	56	20
Univ. of N. Dakota	30	39	23	53	8
S. Dakota St. Coll.	30	55	36	66	82
Superior St. Tchrs. Coll.	19	40	16	60	9
Univ. of Wisconsin	43	43	24	60	25
Univ. of Wyoming	21	43	34	55	25
Mich. Coll. of M&T	48	42	22	68	20
Mich. St. Coll A&AS	87	45	29	63	35
Univ. of Michigan	28	45	30	58	35
Wayne University	38	42	14	61	20

*Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of fifty (P_{50}) means that the school attained a score below which approximately fifty per cent of the school mean scores lie and above which the other fifty per cent lie a percentile rank of ninety (P_{90}) indicates that approximately ninety per cent of the schools attained mean scores below this point and that only ten per cent of the schools achieved scores above this point. Therefore, the 99th percentile is the highest or best percentile ranking and the 1st percentile is the lowest or poorest percentile ranking.

INTRODUCTION TO USAF (continued)

Schools	No. of Students Examined	RAW SCORE (Possible 80) Mean	Lowest	Highest	*Percentile Ranks of 112 Schools
TWELFTH AIR FORCE	725	46	17	68	
University of Arkansas	48	54	39	68	80
Louisiana St. Univ.	55	52	38	66	70
Tulane University	33	46	26	66	40
Southwestern La. Inst.	35	43	17	66	25
New Mexico Coll. of A &MA	41	44	26	64	30
Oklahoma A&M	52	50	35	67	60
Univ. of Okla	78	49	28	63	55
A&M Coll. of Texas	169	42	20	63	20
Baylor University	26	38	18	60	7
Southern Meth. Univ	51	41	19	60	10
Texas Tech College	46	54	34	68	80
University of Texas	91	43	25	64	25

*Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of fifty (P_{50}) means that the school attained a score below which approximately fifty per cent of the school mean scores lie and above which the other fifty per cent lie a percentile rank of ninety (P_{90}) indicates that approximately ninety per cent of the schools attained mean scores below this point and that only ten per cent of the schools achieved scores above this point. Therefore, the 99th percentile is the highest or best percentile ranking and the 1st percentile is the lowest or poorest percentile ranking.

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Schools	No. of Students Examined	Raw Score (Possible 80) Mean	Lowest	Highest	*Percentile Ranks of 112 Schools
FOURTEENTH AIR FORCE	687	48	4	75	
Alabama Poly. Inst.	25	46	32	60	40
Tuskegee Inst.	31	50	4	73	60
Univ. of Alabama	71	38	19	61	7
Univ. of Florida	77	55	39	68	82
Univ. of Miama	33	42	25	62	20
Georgia Inst. of Tech.	52	46	18	75	40
Univ. of Georgia	43	44	26	58	30
Miss. St. College	67	46	23	68	40
Univ. of Miss.	39	43	27	59	25
E. Carolina Teachers Coll.	32	41	24	61	10
N. Carolina St. Coll. of A&E	39	58	44	69	91
Univ. of N. Carolina	55	49	28	66	55
Clemson Agric. Coll.	47	48	24	64	50
The Citadel	56	53	30	72	75
Univ. of Tennesee	20	60	48	69	93

*Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of fifty (P_{50}) means that the school attained a score below which approximately fifty per cent of the school mean scores lie and above which the other fifty per cent lie a percentile rank of ninety (P_{90}) indicates that approximately ninety per cent of the schools attained mean scores below this point and that only ten per cent of the schools achieved scores above this point. Therefore, the 99th percentile is the highest or best percentile ranking and the 1st percentile is the lowest or poorest percentile ranking.

Results of Statistical Control Examination

The 80-item test on Statistical Control was administered to 269 students in 15 schools. The mean score attained by these students from all participating air forces was 51. No comparison by separate air forces was made because the number of schools represented in each of the air forces were too few. However, a distribution of the mean scores of the 15 schools was made and the tabulation is presented in Table 15.

TABLE 15
Distribution of School Averages and Selected Percentiles on the Statistical Control Examination for 15 Schools.

Distribution of Averages		Score Value of Percentiles*	
School Average Scores	No.	Average Score	Percentile
57-59	1	59	99%
54-56	3	54	80%
51-53	6	52	50%
48-50	2		
45-47	1	47	20%
42-44	1		
39-41	0		
36-38	1	38	1%
Total	15		

*Percentiles given here are rough estimates.

The left half part of Table 15 shows that the schol averages range from a low of 36 to a high of 59. Of the 15 schools 9 or 60% attained mean scores between 45 and 53. The schools with the lowest means achieved roughly on the average about two thirds as much as the schools which returned the highest averages. There is nevertheless a wide range in achievement among these schools.

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As an aid in interpreting the school test results the distribution of school averages has been divided into percentiles. Percentiles are points in a distribution of scores below which lie a given percentage of the total number of schools. Five percentile points, P99, P80, P50, P20, P1 with their corresponding score values are given in the right hand part of Table 15. A school average of 59 was achieved by the top 1% of the 15 schools or stated in other words, 99% of the schools attained average scores below 59. An average score of 54 is the score at or below which lie 80% of the school averages. P50, i.e., the fiftieth percentile marks the mid-point of the distribution of school means, that is, it is the point below which roughly 50% of the school averages lie and above which the other 50% lie. An average score of 47 is the score at or below which lie 20% of the school averages, an average score of 38 is the score at or below which lie 1% of the school averages. The majority of the schools attained mean scores between P20 and P80. The range P20-P80 includes the middle 60% of the school averages or stated in terms of score values, the middle 60% of the school averages fell between 47 and 54. Schools attaining averages in the bottom 30%, i.e., P30 or average scores of 49 or below may find it highly desirable to institute changes in methods of instruction, to heighten student interest, and to provide adequate curricular materials. However, in evaluating the achievement of the latter group of schools it is necessary to take into consideration the mental ability of the students concerned. See Chapter 6 for a fuller explanation.

Table 16 gives the mean scores and percentiles for each of the schools which took the examination in Statistical Control.

TABLE 16

Means and Percentile Ranks of Air ROTC Schools Which Took the Statistical Control Examination

AIR ROTC 1943-49

Schools	No. of Students Examined	RAW SCORE (Possible 80) Mean	Lowest	Highest	Percentile* Ranks of 15 Schools
ALL AIR FORCES	269	51	26	69	
FIRST AIR FORCE					
Harvard University	16	53	35	63	65
FOURTH AIR FORCE	27	52	39	68	
University of Oregon	10	51	39	68	46
State Coll. of Wash.	17	53	42	61	65
NINTH AIR FORCE	43	55	35	69	
Ohio University	3	38	35	44	1
Gettysburg College	16	54	35	65	80
University of Penna.	7	56	42	64	88
University of Pittsburgh	17	59	46	69	99
TENTH AIR FORCE	43	50	28	68	
Iowa State College	15	54	45	63	80
State Univ. of Iowa	14	53	38	68	65
Wayne University	14	44	28	55	13
TWELFTH AIR FORCE	64	51	26	69	
University of Arkansas	23	53	45	61	65
University of Oklahoma	41	50	26	69	40

*Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of fifty (P_{50}) means that the school attained a score below which approximately fifty per cent of the school mean scores lie and above which the other fifty per cent lie a percentile rank of ninety (P_{90}) indicates that approximately ninety per cent of the schools attained mean scores below this point and that only ten per cent of the schools achieved scores above this point. Therefore, the 99th percentile is the highest or best percentile ranking and the 1st percentile is the lowest or poorest percentile ranking.

Because of the small number of schools involved the percentile rankings are best estimated values.

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STATISTICAL CONTROL (continued)

Schools	No. of Students Examined	RAW SCORE (Possible 80) Mean	Lowest	Highest	Percentile Ranks of 15 Schools
FOURTEENTH AIR FORCE	74	49	30	61	
Alabama Polytechnic Inst.	29	47	30	60	20
University of Georgia	14	49	47	60	33
University of N. Carolina	31	53	38	61	65

0709

Results of Supply Examination

The 80-item test on Supply was administered to 306 students. No comparison by air force was made because the number of schools represented in each air force were too few. However, a distribution of the mean scores of the 18 participating schools was made and the tabulation is presented in Table 17.

Table 17

Distribution of School Averages and Selected Percentiles on the Supply Examination for 18 Schools Air ROTC 1948-1949

Distribution of Averages		Score Value of Percentiles*	
School Average Scores	No.	Average Score	Percentile
63-65	1	64	99%
60-62	0		
57-59	4	59	90%
		57	80%
54-56	4	55	70%
51-53	1	53	60%
		52	50%
48-50	2	49	40%
45-47	1	46	30%
42-44	4	44	20%
		43	10%
39-41	1	40	1%
Total	18		

*Percentiles given here are rough estimates.

The left half part of Table 17 shows that the school averages range from a low average score of 39 to a high of 65. Of the 18 schools, 12 or 67% attained mean scores between 45 and 59. The schools with the lowest means achieved roughly on the average about two thirds as much as the schools which returned the highest averages. There is a wide range in achievement among these schools.

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As an aid in interpreting the school test results the distribution of school averages has been divided into percentiles. Percentiles are points in a distribution of scores below which lie a given percentage of the total number of schools. Eleven percentile points, P99, P90, P80, P70, P60, P50, P40, P30, P10 and P1, with their corresponding score values are given in the right hand part of Table 17. A school average of 64 was achieved by the top 1% of the 18 schools or stated in other words, 99% of the schools attained average scores below 64. An average score of 59 is the score at or below which lie 90% of the school averages; an average score of 57 is the score at or below which lie 80% of the school averages; an average score of 55 is the score at or below which lie 70% of the school averages. The other percentiles may be interpreted in a similar manner. P50, i.e., the fiftieth percentile marks the mid-point of the distribution of school means, that is, it is the point below which 50% of the school averages lie and above which the other 50% lie. The great majority of the schools attained mean scores between thirty percentile points above P50, i.e., P80; and thirty percentile points below P50, i.e., P20. The range P20 to P80 includes the middle 60% of the school averages or stated in terms of score values, the middle 60% of the school averages fell between 44 and 57. Schools attaining averages in the bottom 30%, i.e., P30 may find it highly desirable to institute changes in methods of instruction, to heighten student interest, and to provide adequate curricular material. However, in evaluating the achievement of the latter group of schools, it is necessary to take into consideration the mental ability of the students concerned. See Chapter 6 for a fuller explanation.

Table 18 gives the mean scores and percentiles for each of the schools which took the examination in Supply.

Table 18

Means and Percentile Ranks of Air ROTC Schools Which Took the Supply Examination

Air ROTC 1948-49

Schools	No. of Students Examined	RAW SCORE (Possible 80)			Percentile* Ranks of 16 Schools
		Mean	Lowest	Highest	
ALL AIR FORCES	306	52	22	76	
FIRST AIR FORCE	34	62	44	76	
University of Connecticut	29	64	45	76	99
Williams College	5	51	44	68	47
FOURTH AIR FORCE	52	54	36	69	
University of Arizona	14	48	36	69	37
University of California at Los Angeles	32	57	43	68	80
Montana State University	6	54	44	68	65
NINTH AIR FORCE	60	56	31	66	
Ohio University	4	59	59	64	90
Ohio State University	29	54	31	66	65
Howard University	14	58	48	66	85
University of Maryland	13	55	45	65	70
TENTH AIR FORCE	73	50	22	75	
Colorado State Colg A&MA	6	44	36	53	20
Indiana University	23	50	37	75	43
University of Wichita	16	43	29	55	10
University of Minnesota	22	46	22	61	30
University of Wisconsin	6	44	31	61	20
TWELFTH AIR FORCE	23				
New Mexico Colg. A&MA	23	40	30	48	1
FOURTEENTH AIR FORCE	64	54	33	71	
University of Florida	21	59	50	71	90
University of Mississippi	13	42	33	59	7
The Citadel	30	56	33	71	75

*Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of 50 (P50) means that the school attained a score below which approximately 50% of the school mean scores lie and above which the other 50% lie. A percentile rank of 90 (P90) indicates that approximately 90% of the schools attained mean scores below this point and that only 10% of the schools achieved scores above this point. Therefore the 99th percentile is the highest or best percentile ranking and the first percentile is the lowest or poorest percentile ranking.

Because of the small number of schools involved the percentile rankings are best estimated values.

0712

Results of Transportation Examination

The 80-item test on Transportation was administered to 219 students in 12 schools. The mean score attained by these students from all participating air forces was 48. No comparison by separate air forces was made because the number of schools represented in each of the air forces were too few. However, a distribution of the mean scores of the 12 schools was made and the tabulation is given in Table 19.

Table 19

Distribution of School Averages and Selected Percentiles on the Transportation Examination for 12 Schools

Air ROTC 1948-1949

Distribution of Averages		Score Value of Percentiles*	
School Average Scores	No.	Average Score	Percentile
72-74	1	72	99%
69-71	0		
66-68	1		
63-65	1		
60-62	0		
57-59	0	57	80%
54-56	0		
51-53	0		
48-50	0		
45-47	2	47	50%
42-44	2		
39-41	1		
36-38	2	36	20%
33-35	0		
30-32	2	30	1%
Total	12		

*Percentiles given here are rough estimates.

The left half part of Table 19 shows that the school averages range from a low of 30 to a high of 74. Of the 12 schools, 7 or about 58 per cent attained mean scores between 36 and 47. The schools with the lowest means achieved roughly on the average about 45 per cent as much as the schools which returned the highest averages. The range of school achievement is greatest on the Transportation examination.

As an aid in interpreting the school test results the distribution of school averages has been divided into percentiles. Percentiles are points in the distribution of scores below which lie a given percentage of the total number of schools. Five percentile points; P99, P80, P50, P20 and P1 with their corresponding score values are given in the right hand part of Table 19. A school average of 72 was achieved by the top one percent (1%) of the 12 schools or stated in other words, 99% of the schools attained average scores below 72. An average score of 57 is the score at or below which lie 80% of the school averages. P50, i.e., the fiftieth percentile marks the mid-point of the distribution of school means, that is, it is the point below which roughly fifty per cent (50%) of the school averages lie and above which the other fifty per cent (50%) lie. An average score of 36 is the score at or below which lie 20% of the school averages; an average score of 38 is the score at or below which lie 1 per cent of the school averages. The majority of the schools attained mean scores between P20 and P80. The range P20-P80 includes the middle sixty per cent (60%) of the school averages or stated in terms of score values the middle sixty per cent (60%) of the school averages fell between 36 and 57. Schools attaining averages in the bottom thirty per cent (30%) i.e., P30 or average scores of 38 or below may find it highly desirable to institute changes in methods of instruction, to heighten student interest, and to provide adequate curricular methods. However, in evaluating the achievement of the latter group of schools, it is necessary to take into consideration the mental ability of the students concerned. See Chapter 6 for a fuller explanation.

Table 20 gives the mean scores and percentiles for each of the schools which took the examination in Transportation.

Table 20

Means and Percentile Ranks of Air ROTC Schools Which Took the Transportation Examination

Air ROTC 1948-1949

Schools	No. of Students Examined	RAW SCORE (Possible 80) Mean	Lowest	Highest	Percentile Ranks of 12 Schools
ALL AIR FORCES	219	48	23	78	
FIRST AIR FORCE	28	56	33	75	
University of Massachusetts	15	67	56	75	92
Syracuse University	13	43	33	50	41
FOURTH AIR FORCE	42	37	23	55	
San Jose State College	22	41	24	55	35
Oregon State College	20	32	23	42	7
NINTH AIR FORCE	33	38	24	58	
University of Akron	12	37	28	48	35
Lehigh University	8	30	24	40	1
Howard University	13	44	31	58	44
TENTH AIR FORCE	24	50	27	78	
Coe College	15	36	27	50	20
South Dakota State College	9	72	65	78	99
TWELFTH AIR FORCE	35				
University of Arkansas	35	47	33	61	50
FOURTEENTH AIR FORCE	57	58	30	78	
Tuskegee Institute	39	64	38	78	85
Clemson Agricultural College	18	45	30	65	47

*Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile rank of 50 (P50) means that the school attained a score below which approximately 50% of the school mean scores lie and above which the other 50% lie. A percentile rank of 90 (P90) indicates that approximately 90% of the schools attained mean scores below this point and that only 10% of the schools achieved scores above this point. Therefore the 99th percentile is the highest or best percentile ranking and the first percentile is the lowest or poorest percentile ranking.

Because of the small number of schools involved the percentile rankings are best estimated values.

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CHAPTER III

COMPARISON OF RANK ORDERS OF AIR ROTC SCHOOLS ON EIGHT COURSE EXAMINATIONS IN 1947-1948 and 1948-1949

This short section will deal with the question, To what degree do Air ROTC schools maintain their rank order of merit from 1947-1948 course examination to the 1948-1949 course examination? Based on the results of each course examination each school was placed in a rank order of merit, that is, the school with the highest mean score was given a rank of one (1), the school with the second highest score was given a rank of two (2), and so on. In order to make a valid comparison of the rank orders on any one course examination the schools which took the examination in 1947-48 must be compared with the same set of schools which took a similar examination in 1948-1949. Therefore, schools which took a course examination in 1947-1948 but did not take a similar course examination in 1948-1949 and schools which took the course examination in 1948-1949 but were not in the program to take a similar examination in 1947-1948 were not included in this comparison.

Differences among the schools were expressed by ranking the schools in one-two-three order. If the schools in 1947-1948 tend to maintain the same ranks in 1948-1949 then the correlation, that is, the relationship between the two sets of annual ranks is positive. If the schools in 1947-1948 reverse their rank order, that is, the schools that ranked near the top in 1947-1948 tended to rank toward the bottom and vice versa then the correlation is negative. The degree of correlation between two sets of measures can be indicated by coefficients. These coefficients of correlation may range from

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+ 1.00 to 0 to -1.00. It is customary to describe the correlation between two ranks or measures as high, marked or substantial, low or negligible. Coefficients of correlation between -.20 to 0 to + .20 denote negligible relationship, between + .21 to + .40 denote low or slight relationship, between + .41 to + .70 denote substantial relationship, between + .71 to + 1.00 denote close to very high relationship. Negative coefficients of correlation between -.21 to -.40, -.41 to -.70 and -.71 to -1.00 indicate corresponding degrees of inverse relationship.

The coefficients of correlations which will be presented have been calculated from a few cases and are, therefore, not very reliable; however, their chief value lies in suggesting the possible presence of relationship, as in a preliminary survey.

In all eight coefficients of correlations were computed, that is, one for each pair of annual ranks for each of the eight course examinations. The correlations range from substantial positive degree of relationship to a low or negligible relationship. None of the correlations were negative although some approached zero or no relationship at all. The coefficients of correlation between school ranks on 1947-1948 examination with the school ranks on the 1948-1949 examination in each course are as follows:

	COURSE EXAMINATION	COEFFICIENT OF CORRELATION	INTERPRETATION
1.	Armament	+ .70	Close positive relationship.
2.	Introduction to USAF	+ .50	Substantial positive relationship.

COURSE EXAMINATION	COEFFICIENT OF CORRELATION	INTERPRETATION
3. Administration and Military Management	+ .35	Slight positive relationship.
4. Communications	+ .33	Slight positive relationship.
5. Supply	+ .28	Slight positive relationship.
6. Statistical Control	+ .22	Slight positive relationship.
7. Aircraft Maintenance	+ .16	Negligible positive relationship.
8. Transportation	+ .06	Negligible positive relationship.

The course examinations where the highest positive correlations were obtained were Armament, Introduction to USAF and Administration and Military Management. On the latter examinations there was a tendency for schools to maintain their status rankings from 1947-1948 to 1948-1949. The three course examinations where the coefficients were lowest were Aircraft Maintenance, Statistical Control and Transportation. On the latter three examinations, therefore, there was a tendency for the schools to change their status ranks, that is, those that were high on the 1947-1948 examination were low on the 1948-1949 examination and vice versa.

These changes may be due to several factors; changes in effectiveness of course instruction, changes in student motivation, changes in course content, changes in instructor personnel and changes in the quality of mental ability of the student population. Changes in the difficulty of the two annual examinations in a subject field would not affect too greatly the inter-school comparisons because the examinations would be equally difficult or easy for both annual

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groups of schools and, therefore, would have little effect on the relative positions or rank orders of the schools concerned.

Tables 21 to 28 present the comparisons of rank orders of Air ROTC Schools on 1947-1948 and 1948-1949 examinations in each of the eight course fields.

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TABLE 21

COMPARISON OF RANK ORDERS OF THIRTY-NINE AIR ROTC SCHOOLS ON THE 1947-1948 and 1948-1949 EXAMINATIONS IN ADMINISTRATION AND MILITARY MANAGEMENT

Examination in Administration and Military Management Air ROTC 1947-1948		Examination in Administration and Military Management Air ROTC 1948-1949	
Schools	* Rank Order 1947-1948	Schools	* Rank Order 1948-1949
FIRST AIR FORCE		FIRST AIR FORCE	
Yale University	3.5	Yale University	7.5
Boston University	25	Boston University	26
Fordham University	7	Fordham University	10
New York University	1	New York University	3
Syracuse University	19	Syracuse University	7.5
FOURTH AIR FORCE		FOURTH AIR FORCE	
University of Utah	7	University of Utah	19
Utah State Agricultural College	2	Utah State Agricultural College	2
University of Oregon	22	University of Oregon	24
NINTH AIR FORCE		NINTH AIR FORCE	
University of Kentucky	38	University of Kentucky	36
West Kentucky St. Teachers	3.5	West Kentucky St. Teachers	24
Johns Hopkins University	37	John Hopkins University	16
University of Akron	19	University of Akron	1
University of Cincinnati	27	University of Cincinnati	18
Duquesne University	22	Duquesne University	34
Penn St. College	30	Penn State College	13
Virginia Military Inst.	25	Virginia Military Inst.	12
Virginia Poly. Tech. Inst.	10.5	Virginia Poly. Tech. Inst.	28
W. Virginia University	35.5	W. Virginia University	5

*A Rank Order of 1 is the highest, 2 is the next highest, etc.

TABLE 21 continued

Examination in Administration and Military Management Air ROTC 1947-1948 — Schools	* Rank Order 1947-1948	Examination in Administration and Military Management Air ROTC 1948-1949 — Schools	* Rank Order 1947-1948
TENTH AIR FORCE		**TENTH AIR FORCE**	
University of Illinois	25	University of Illinois	22
University of Iowa	16	University of Iowa	8
Kansas State College	33.5	Kansas State College	9
University of Kansas	30	University of Kansas	20
University of Wichita	16	University of Wichita	20
University of Missouri	7	University of Missouri	10
University of Nebraska	7	University of Nebraska	4
University of No. Dakota	13	University of No. Dakota	32
University of Wyoming	35.5	University of Wyoming	32
No. Dakota St. Ag. Coll.	33.5	No. Dakota St. Ag. Coll.	32
Michigan St. Coll. of A & AS	16	Michigan St. Coll. of A & AS	39
TWELFTH AIR FORCE		**TWELFTH AIR FORCE**	
Oklahoma A & M	28	Oklahoma A & M	22
A & M College of Texas	30	A & M College of Texas	38
Texas Tech College	10.5	Texas Tech College	14
University of Texas	22	University of Texas	26
FOURTEENTH AIR FORCE		**FOURTEENTH AIR FORCE**	
University of Alabama	13	University of Alabama	34
University of Florida	19	University of Florida	14
Georgia Tech. Inst.	7	Georgia Tech. Inst.	16
University of Georgia	22	University of Georgia	28
Mississippi State Coll.	39	Mississippi State Coll.	30
University of Mississippi	13	University of Mississippi	37

TABLE 22

COMPARISON OF RANK ORDERS OF TWENTY-ONE AIR ROTC SCHOOLS ON THE 1947-1948 and 1948-1949 EXAMINATIONS IN AIRCRAFT MAINTENANCE

Aircraft Maintenance Examination Air ROTC 1947-1948		Aircraft Maintenance Examination Air ROTC 1948-1949	
Schools	*Rank Order 1947-1948	Schools	* Rank Order 1948-1949
FIRST AIR FORCE		FIRST AIR FORCE	
University of New Hampshire	13	University of New Hampshire	6
Rutgers University	4	Rutgers University	21
FOURTH AIR FORCE		FOURTH AIR FORCE	
University of Arizona	13	University of Arizona	18
Stanford University	5	Stanford University	15
University of Nevada	13	University of Nevada	19
University of Washington	16	University of Washington	11
NINTH AIR FORCE		NINTH AIR FORCE	
University of Kentucky	10	University of Kentucky	11
University of Maryland	10	University of Maryland	8
Penn. State Coll.	7.5	Penn. State Coll.	1
West Virginia Univ.	19	West Virginia Univ.	5
TENTH AIR FORCE		TENTH AIR FORCE	
Purdue University	6	Purdue University	15
University of Illinois	3	University of Illinois	8
University of Wisconsin	17	University of Wisconsin	8
Michigan College of M & T	21	Michigan Coll. of M & T	13
TWELFTH AIR FORCE		TWELFTH AIR FORCE	
Oklahoma A & M	7	Oklahoma A & M	17
Univ. of Oklahoma	13	University of Oklahoma	13
A & M College of Texas	20	A & M College of Texas	19

*A Rank Order of 1 is the highest, 2 is the next highest, etc.

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TABLE 22 continued

Aircraft Maintenance Examination Air ROTC 1947-1948		Aircraft Maintenance Examination Air ROTC 1948-1949	
Schools	Rank Order 1947-1948	Schools	Rank Order 1948-1949
FOURTEENTH AIR FORCE		FOURTEENTH AIR FORCE	
Alabama Polytechnic Inst.	17	Alabama Polytechnic Inst.	4
Georgia Tech.	1	Georgia Tech.	3
North Carolina St. Coll.	2	North Carolina St. Coll.	2
Clemson Ag. College	10	Clemson Ag. College	11

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TABLE 23
COMPARISON OF RANK ORDERS OF SIX AIR ROTC SCHOOLS ON THE 1947-1948 and 1948-1949 EXAMINATIONS IN ARMAMENT

Armament Examination Air ROTC 1947-1948		Armament Examination Air ROTC 1948-1949	
Schools	* Rank Order 1947-1948	Schools	*Rank Order 1948-1949
FIRST AIR FORCE		FIRST AIR FORCE	
FOURTH AIR FORCE		FOURTH AIR FORCE	
Utah St. Ag. Coll.	1	Utah St. Ag. Coll.	1
NINTH AIR FORCE		NINTH AIR FORCE	
Georgetown University	6	Georgetown University	6
TENTH AIR FORCE		TENTH AIR FORCE	
Univ. of Missouri	5	Univ. of Missouri	2
TWELFTH AIR FORCE		TWELFTH AIR FORCE	
Texas Tech College	4	Texas Tech College	5
FOURTEENTH AIR FORCE		FOURTEENTH AIR FORCE	
Mississippi St. College	3	Mississippi St. College	4
University of Tennessee	2	University of Tennessee	3

*A Rank Order of 1 is the highest, 2 is the next highest, etc.

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TABLE 24

COMPARISON OF RANK ORDERS OF EIGHT AIR ROTC SCHOOLS ON THE 1947-1948 and 1948-1949 EXAMINATIONS IN COMMUNICATIONS

Communications Examination Air ROTC 1947-1948		Communications Examination Air ROTC 1948-1949	
Schools	*Rank Order 1947-1948	Schools	*Rank Order 1948-1949
FIRST AIR FORCE		FIRST AIR FORCE	
Mass. Inst. of Tech.	1	Mass. Inst. of Tech.	7
FOURTH AIR FORCE		FOURTH AIR FORCE	
Oregon State College	7	Oregon State College	5.5
NINTH AIR FORCE		NINTH AIR FORCE	
Lehigh University	8	Lehigh University	8
TENTH AIR FORCE		TENTH AIR FORCE	
Iowa State College	6	Iowa State College	3.5
University of Minnesota	2	University of Minnesota	3.5
University of Nebraska	5	University of Nebraska	5.5
TWELFTH AIR FORCE		TWELFTH AIR FORCE	
FOURTEENTH AIR FORCE		FOURTEENTH AIR FORCE	
N.C. State College	3	N.C. State College	2
Univ. of Tennessee	4	University of Tennessee	1

*A Rank Order of 1 is the highest, 2 is the second highest, etc.

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TABLE 25

COMPARISON OF RANK ORDERS OF NINETY AIR ROTC SCHOOLS ON THE 1947-1948 and 1948-1949 EXAMINATIONS IN INTRODUCTION TO USAF

Introduction to USAF Examination Air ROTC 1947-1948		Introduction to USAF Examination Air ROTC 1948-1949	
Schools	*Rank Order 1947-1948	Schools	* Rank Order 1948-1949
FIRST AIR FORCE		FIRST AIR FORCE	
University of Connecticut	4	University of Connecticut	9
Yale University	12	Yale University	5.5
Boston University	29	Boston University	27.5
Harvard University	17	Harvard University	48.5
Mass. Inst. of Tech.	46	Mass. Inst. of Tech.	79.5
Univ. of Mass.	22.5	Univ. of Mass.	36
Williams College	12	Williams College	48.5
Rutgers University	64	Rutgers University	79.5
Colgate University	34	Colgate University	53
Cornell University	17	Cornell University	19
Fordham University	58	Fordham University	13.5
New York University	1	New York University	1
Syracuse University	39.5	Syracuse University	40.5
University of New Hampshire	52	University of New Hampshire	32
FOURTH AIR FORCE		FOURTH AIR FORCE	
Univ. of Arizona	64	University of Arizona	48.5
Stanford University	17	Stanford University	13.5
Montana State College	22.5	Montana State College	23.5
University of Nevada	75.5	University of Nevada	87
Oregon State College	75.5	Oregon State College	71.5
University of Oregon	39.5	University of Oregon	40.5
Utah St. Ag. Coll.	58	Utah St. Ag. Coll.	56.5
University of Utah	39.5	University of Utah	56.5
State Coll. of Washington	69.5	State Coll. of Washington	19
University of Wash.	39.5	University of Wash.	53
University of Idaho	3	University of Idaho	4

*A Rank Order of 1 is the highest, 2 is the next highest, etc.

TABLE 25 continued

Introduction to USAF Examination Air ROTC 1947-1948		Introduction to USAF Examination Air ROTC 1948-1949	
Schools	Rank Order 1947-1948	Schools	Rank Order 1948-1949
NINTH AIR FORCE		NINTH AIR FORCE	
University of Kentucky	83	University of Kentucky	2
West Kentucky State	12	West Kentucky State	66
Johns Hopkins Univ.	22.5	John Hopkins Univ.	15.5
Univ. of Maryland	58	Univ. of Maryland	79.5
Ohio State Univ.	29	Ohio State Univ.	66
Ohio University	39.5	Ohio University	45.5
University of Akron	12	University of Akron	32
University of Cincinnati	12	University of Cincinnati	32
Duquesne University	64	Duquesne University	79.5
Gettysburg Coll.	20	Gettysburg Coll.	9
Lehigh Univ.	22.5	Lehigh Univ.	19
Penn State Coll.	52	Penn State Coll.	61.5
University of Penn.	29	University of Penn.	23.5
Univ. of Pittsburgh	17	Univ. of Pittsburgh	11.5
Virginia Military Inst.	52	Virginia Military Inst.	5.5
Virginia Poly. Inst.	29	Virginia Poly. Inst.	66
West Virginia Univ.	52	West Virginia Univ.	40.5
Georgetown Univ.	75.5	Georgetown Univ.	87.5
Howard University	86	Howard University	90
TENTH AIR FORCE		TENTH AIR FORCE	
Colorado St. Coll.	29	Colorado St. Coll.	79.5
Univ. of Denver	39.5	Univ. of Denver	40.5
University of Ill.	17	University of Ill.	15.5
Indiana University	88.5	Indiana University	27.5
Purdue Univ.	29	Purdue Univ.	36
Univ. of Notre Dame	47	Univ. of Notre Dame	32
Coe College	58	Coe College	53
Iowa St. Coll.	8.5	Iowa St. Coll.	61.5
St. Univ. of Iowa	75.5	St. Univ. of Iowa	79.5
Kansas St. Coll.	88.5	Kansas St. Coll.	9
Univ. of Kansas	47	Univ. of Kansas	27.5
Univ. of Wichita	5.5	Univ. of Wichita	3
Univ. of Minn.	39.5	Univ. of Minn.	36
St. Louis Univ.	7	St. Louis Univ.	71.5
Univ. of Missouri	39.5	University of Missouri	45.5
Univ. of Nebraska	58	Univ. of Nebraska	32
No. Dakota Ag. Coll.	75.5	No. Dakota Ag. Coll.	79.5
University of North Dakota	29	University of N.Dakota	85
So. Dakota St. Coll.	8.5	So. Dakota St. Coll.	19
Univ. of Wisconsin	69.5	Univ. of Wisconsion	71.5
Univ. of Wyoming	29	Univ. of Wyoming	71.5

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TABLE 25 continued

Introduction to USAF Examination
Air ROTC 1947-1948

Schools	Rank Order 1947-1948
TENTH AIR FORCE	
Michigan Coll. of M & T	69.5
Michigan St. Coll. of A & AS	46
University of Michigan	39.5
Wayne University	64
TWELFTH AIR FORCE	
Univ. of Arkansas	5.5
Tulane University	58
New Mexico Coll. of A&MA	80.5
Oklahoma A & M	83
University of Oklahoma	39.5
A & M College of Texas	79
Texas Tech College	69.5
University of Texas	47
FOURTEENTH AIR FORCE	
Alabama Poly. Tech	86
Tuskegee Inst.	90
Univ. of Alabama	52
University of Florida	69.5
Georgia School of Tech	2
Univ. of Georgia	69.5
Miss. St. Coll.	83
Univ. of Miss.	75.5
No. Carolina St. Coll	64
Univ. of N. Carolina	58
Clemson Agri. Coll.	86
The Citadel	80.5
Univ. of Tennessee	29

Introduction to USAF Examination
Air ROTC 1948-1949

Schools	Rank Order 1948-1949
TENTH AIR FORCE	
Michigan Coll. of M & T	79.5
Michigan St. Coll. of A & AS	61.5
University of Michigan	61.5
Wayne University	79.5
TWELFTH AIR FORCE	
Univ. of Arkansas	23.5
Tulane University	56.5
New Mexico Coll. of A&MA	66
Oklahoma A & M	40.5
University of Oklahoma	45.5
A & M College of Texas	79.5
Texas Tech College	23.5
University of Texas	71.5
FOURTEENTH AIR FORCE	
Alabama Poly. Tech	56.5
Tuskegee Inst.	40.5
Univ. of Alabama	87.5
University of Florida	19
Georgia School of Tech.	56.5
Univ. of Georgia	66
Miss. St. Coll.	56.5
University of Miss.	71.5
No. Carolina St. Coll.	11.5
University of N. Carolina	45.5
Clemson Agri. Coll.	48.5
The Citadel	27.5
Univ. of Tennessee	7

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TABLE 26

COMPARISON OF RANK ORDERS OF EIGHT AIR ROTC SCHOOLS ON THE 1947-1948 and 1948-1949 EXAMINATIONS IN STATISTICAL CONTROL

Statistical Control Examination Air ROTC 1947-1948		Statistical Control Examination Air ROTC 1948-1949	
Schools	* Rank Order 1947-1948	Schools	* Rank Order 1948-1949
FIRST AIR FORCE		FIRST AIR FORCE	
———————		———————	
FOURTH AIR FORCE		FOURTH AIR FORCE	
Univ. of Oregon	7	Univ. of Oregon	4
St. Coll. of Wash.	5	St. Coll. of Wash.	2.5
NINTH AIR FORCE		NINTH AIR FORCE	
Ohio Univ.	3	Ohio Univ.	8
TENTH AIR FORCE		TENTH AIR FORCE	
Iowa St. Coll.	3	Iowa State Coll.	1
TWELFTH AIR FORCE		TWELFTH AIR FORCE	
Univ. of Arkansas	3	University of Arkansas	2.5
Univ. of Oklahoma	1	University of Oklahoma	5
FOURTEENTH AIR FORCE		FOURTEENTH AIR FORCE	
Alabama Poly. Inst.	8	Alabama Poly. Inst.	7
Univ. of Georgia	6	Univ. of Georgia	6

*A Rank Order of 1 is the highest, 2 is the next highest, etc.

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TABLE 27

COMPARISON OF RANK ORDERS OF FOURTEEN AIR ROTC SCHOOLS ON THE 1947-1948 and 1948-1949 EXAMINATIONS IN SUPPLY

Supply Examination Air ROTC 1947-1948		Supply Examination Air ROTC 1948-1949	
Schools	* Rank Order 1947-1948	Schools	* Rank Order 1948-1949
FIRST AIR FORCE		FIRST AIR FORCE	
Univ. of Conn.	6.5	Univ. of Conn.	1
FOURTH AIR FORCE		FOURTH AIR FORCE	
Montana State Univ.	8	Montana State Univ.	7.5
NINTH AIR FORCE		NINTH AIR FORCE	
Ohio Univ.	2	Ohio Univ.	2.5
Ohio St. Univ.	13	Ohio St. Univ.	7.5
Howard Univ.	1	Howard Univ.	4
Univ. of Maryland	12	Univ. of Maryland	6
TENTH AIR FORCE		TENTH AIR FORCE	
Col. St. Coll. of A & M	10.5	Col. St. Coll. of A & M	11.5
Indiana Univ.	3	Indiana Univ.	9
Univ. of Minn.	6.5	Univ. of Minn.	10
Univ. of Wisconsion	4.5	Univ. of Wisconsion	11.5
TWELFTH AIR FORCE		TWELFTH AIR FORCE	
New Mexico Coll. of A & M A	9	New Mexico Coll. of A & M A	14
FOURTEENTH AIR FORCE		FOURTEENTH AIR FORCE	
The Citadel	14	The Citadel	5
Univ. of Florida	4.5	Univ. of Florida	2.5
Univ. of Miss.	10.5	Univ. of Miss.	13

*A Rank Order of 1 is the highest, 2 is the next highest, etc.

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TABLE 28

COMPARISON OF RANK ORDERS OF NINE AIR ROTC SCHOOLS ON THE 1947-1948 - and 1948- 1949 EXAMINATIONS IN TRANSPORTATION

Transportation Examination Air ROTC 1947- 1948		Transportation Examination Air ROTC 1948-1949	
Schools	* Rank Order 1947-1948	Schools	* Rank Order 1948-1949
FIRST AIR FORCE		FIRST AIR FORCE	
Syracuse Univ.	6	Syracuse Univ.	6
FOURTH AIR FORCE		FOURTH AIR FORCE	
Oregon State College	7	Oregon State College	9
NINTH AIR FORCE		NINTH AIR FORCE	
Univ. of Akron	8	Univ. of Akron	7
Howard Univ.	4	Howard University	5
TENTH AIR FORCE		TENTH AIR FORCE	
Coe College	1	Coe College	8
S. Dakota St. Coll.	2.5	S. Dakota St. Coll.	1
TWELFTH AIR FORCE		TWELFTH AIR FORCE	
Univ. of Arkansas	5	Univ. of Arkansas	3
FOURTEENTH AIR FORCE		FOURTEENTH AIR FORCE	
Tuskegee Inst.	9	Tuskegee Inst.	2
Clemson Ag. Coll.	2.5	Clemson Ag. Coll.	4

*A Rank Order of 1 is the highest, 2 is the next highest, etc.

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CHAPTER IV

ANALYSIS OF TEST ITEMS ON THE ANNUAL AIR ROTC COURSE EXAMINATIONS

General Summary

Each of the eight course examinations contained eighty items. The performance of each item was carefully scrutinized. Each item was analyzed for two important aspects, validity and difficulty. Item validity is concerned with the ability of the item to differentiate between good students and poor students. Good students are students who do well in the course examination, and poor students are those who do poorly in the examination. Good discriminating power is indicated by positive validity coefficients. Validity coefficients may range from -1.00 to 0 to +1.00. A valid test of the type under consideration should contain items whose validity coefficients are close to .25 or better.

A summary of the item validities and the item difficulties are given in subsequent tables. Table 29 gives the distribution of item validities for each of the eight course examinations. The item validities were distributed into five categories after being rated as follows:

Validity coefficients .14 and below were rated poor;
Validity coefficients .15 to .24 were rated fair;
Validity coefficients .25 to .34 were rated good;
Validity coefficients .35 to .44 were rated very good;
Validity coefficients .45 and above were rated excellent.

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Table 29

Validity Coefficients of the Eighty Items on Each of the Eight Air ROTC Course Examinations Rated on a Five Category Basis

Course Examination	Percentage of Items in Each of the Five Categories: Excellent	Very Good	Good	Fair	Poor
Administration and Military Management	36%	29%	21%	10%	4%
Aircraft Maintenance Engineering	16%	25%	29%	21%	9%
Armament	51%	22%	13%	10%	4%
Communications	25%	31%	20%	14%	10%
Introduction to USAF	60%	23%	12%	4%	1%
Statistical Control	2%	14%	29%	34%	21%
Supply	19%	17%	24%	28%	12%
Transportation	48%	15%	16%	11%	10%

The course examination with the highest percent of excellent items and the one with the lowest per cent of poor items were Introduction to USAF and Armament respectively. The course examination with the lowest per cent of excellent items and the highest per cent of poor items is that in Statistical Control.

A briefer method of comparing the respective examinations from the point of view of validity coefficients is to calculate the per cent of items that reached the standard of .25 or better. This comparison is given below:

Air ROTC Course Examination	Percentage of Test Items Which Met the Standard of .25 or Better
Administration and Military Management	86%
Aircraft Maintenance Engineering	70%
Armament	86%
Communications	76%
Introduction to USAF	95%
Statistical Control	45%
Supply	89%
Transportation	79%

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The three examinations having the highest per cent of items meeting the standard of .25 or better are Introduction to USAF, Armament and Administration and Military Management. Introduction to USAF had the highest percentage, namely, 95 per cent. Of the eight examinations, all except that on Statistical Control meet acceptable standards from the point of view of item validity.

How do the item validities of the examinations of 1947-1948 compare with those of 1948-1949? A short method to use for comparing tests as to item validities is to compare the average of the eighty item validities. Table 30 presents the data essential for comparing the item validities over the past two years.

Table 30

Comparison of Average Item Validity Coefficients of Each Course Air ROTC Examination for Years 1947-1948 and 1948-1949

Course Examination	Average Item Validity Coefficient, 1947-48	Average Item Validity Coefficient, 1948-49
Administration and Military Management	.31	.40
Aircraft Maintenance	.29	.32
Armament	.22	.45
Communications	.31	.35
Introduction to USAF	.44	.45
Statistical Control	.26	.23
Supply	.29	.31
Transportation	.25	.40

All course examinations except that in Statistical Control show improvement in average item validity. The course examination in

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Introduction to USAF ranked first in both years. As a group, the 1948-1949 examinations show a very high order of merit in the matter of overall item validity.

Item Difficulty

Each test item was analyzed for its difficulty, that is, the number or per cent of the students who were able to answer the item correctly. Theoretically, in a good test there should be a proper proportion of easy, average and difficult items so that the average per cent difficulty of all the items in a test would be about fifty (50) per cent. However, in practice for most scholastic course examinations, an acceptable average per cent difficulty would be in the neighborhood of 60 to 65 per cent. Under certain circumstances the average per cent difficulty may be raised to 70 percent.

The analysis of the items as to validity coefficients is an important one to make for the instructor as an examiner. However, an analysis of the items from the point of view of the instructor as a teacher is one that tells how the items were passed or failed by the students on an Air-Force-wide basis.

The following tabular arrangement groups the items of each examination into ten categories of item-difficulty or item-pass percentages. For example, the number of items on the Administration and Military Management examination passed by 91% to 100% of the students tested was eight (8). Table 31 shows the distribution of the item-difficulty percents for all eight-course examinations.

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Table 31

Number of Items in Specified Student Pass-Per Cent Intervals for Each Air ROTC Course Examination

Course Examination	Item-Difficulty Per Cents Grouped in Ten Per Cent Interva									
	100% to 91%	90% to 81%	80% to 71%	70% to 61%	60% to 51%	50% to 41%	40% to 31%	30% to 21%	20% to 11%	10% or Less
Administration and Military Management	8	15	15	21	11	6	4	0	0	0
Aircraft Maintenance	9	20	21	14	7	3	4	1	0	0
Armament	12	16	17	20	9	4	1	1	0	0
Communications	7	15	23	15	8	10	1	1	0	0
Introduction to USAF	6	11	21	20	8	7	1	5	1	0
Statistical Control	10	14	20	15	12	5	3	0	1	0
Supply	8	25	13	10	10	11	3	0	0	0
Transportation	3	21	14	16	15	5	5	1	0	0

Table 31 reveals that all examinations showed a deficiency of item-difficulty per cents in the intervals from 30 per cent and below. The bulk of the item-difficulty per cents were in the itervals between 61% to 90% There are too many items appearing in the interval 100% to 91% difficulty; in other words, there are too many easy items included on all the examinations except, perhaps, the test on Transportation. Of the eight examinations, that for Introduction to USAF shows a fairly good dispersion and allotment of item-difficulties.

How difficult or how easy were the examinations of 1948-1949 as compared with those of 1947-1948? The data presented in Table 32 helps to answer this question. The average of all the pass-per cents on each examination was obtained. The average per cent difficulty is the average

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of the pass-per cents of the eighty items composing the examinations. Table 32 gives the average per cent difficulty of each examination for the years 1947-1948 and 1948-1949.

Table 32

Comparison of Average Per Cent Difficulty
For Eight Air ROTC Course Examinations For
Years 1947-1948 and 1948-1949

Course Examination	Average Per Cent Difficulty 1947-1948	Average Per Cent Difficulty 1948-1949
Administration and Military Management	64%	70%
Aircraft Maintenance	64%	73%
Armament	67%	72%
Communications	63%	71%
Introduction to USAF	58%	67%
Statistical Control	68%	70%
Supply	57%	71%
Transportation	68%	68%
Average of 8 Examinations	63.6%	70.2%

In all eight examinations the average per cent difficulty for 1948-1949 was equal or higher than those for 1947-1948. The average of the eight average per cent difficulties for 1947-1948 was 63.6%, while the average of the eight average difficulties for 1948-1949 was 70.2%. It is felt that for this type of annual examination, and in view of the purposes for which it is anticipated that it will be put, the average difficulty should not go beyond 65 to 70 per cent.

Subsequent sections of this chapter present a detailed analysis of the worth and value of items in each of the course examinations. Instructors should give close study to the section pertaining to their course field. Among other uses for which the detailed analysis of the performance of the test items will serve, the instructor should plan to review the item data with a view toward obtaining a deeper insight into the manner in which test items behave and thus improve his skill in constructing future examinations.

Administration and Military Management Examination

This examination consisted of eighty (80) multiple-choice items designed to measure student understanding of administrative practices and military management. A sample of four hundred (400) student papers were separated into five (5) ability groups, using total score as the criterion.

Test items were analyzed for their discriminating power, that is, their power to differentiate good students from poor students. Good discriminating power is indicated by positive validity coefficients and poor discriminating power is indicated by negative validity coefficients. Validity coefficients may range from -1.00 to 0 to +1.00. A valid test should contain items whose validity coefficients are at least .25 or better. Sixty-nine (69) of the eighty (80) items measured up to the standard of .25 or better for a discriminating item. The average validity coefficient for all test items was .40 compared with an index of .31 for a similar test which was administered last year. This represents a definite improvement in the discriminating power of the test.

This year's test items had an average difficulty of seventy per cent (70%) correct. They were slightly easier than test items (average difficulty 64% correct) of a similar test which was administered a year ago. The average per cent difficulty is the average of the pass-per cents of the eighty (80) items. The number of items of a specified difficulty is as follows:

	Difficulty (Per cent right)			
	50% and Below	51% to 90%	91% to 100%	Total Test
Number of items	10	62	8	80

A number of items are cited in which all incorrect alternatives were serving as effective distractors: 2, 3, 5, 7, 8, 9, 12, 16, 18, 21, 23, 24, 25, 27, 30 through 36, 38, 41, 44 through 50, 52, 54 through 56, 59 through 61, 63 through 66, 68, 73, 77, 78 and 80. The analysis of test items shows ineffective alternatives which might well be replaced by more plausible distractors. The alternatives listed below should be replaced, as they were chosen more frequently by good students than by poor ones:

Item	Alternative
4	A
37	D
42	B
51	C
53	D
57	B, E
58	C

In order to obtain a quick overview as to which items were excellent, very good, good, fair and poor, a distribution of eighty (80) items according to the degree of validity coefficient was made and given in Table 33.

Table 33

Validity Coefficients of the Eighty Items on the Administration and Military Management Examination

Coefficients .14 and below (Poor)	Coefficients .15 to .24 (Fair)	Coefficients .25 to .34 (Good)	Coefficients .35 to .44 (Very Good)		Coefficients .45 and above (Excellent)	
Item No.	Item No.	Item No.	Item No.		Item No.	
10	13	4	3	37	1	42
17	15	14	5	43	2	46
39	19	25	6	44	8	48
	26	27	7	45	9	50
	51	28	11	52	12	53
	69	29	20	54	16	55
	70	36	21	56	18	59
	71	40	22	58	30	63
		47	23	61	31	64
		49	24	77	32	68
		60	34		33	72
		62			35	76
		65			38	78
		66			41	79
		67				
		74				
		80				

The number and per cent of the items in each of the five (5) categories is as follows:

Category	Number of Items	Percent of Total (80)
Excellent	29	36%
Very Good	23	29%
Good	17	21%
Fair	8	10%
Poor	3	4%

About thirty-six per cent (36%) of the items are excellent; in all about eighty-six per cent (86%) of the items have a rating of good or better.

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The analysis of the items as to validity coefficients is an important one to make for the instructor as an examiner. However, an equally significant analysis of the items from the point of view of the instructor as a teacher is the one that reveals the specific strengths and weaknesses of the students. The indicated strengths reflect areas where the instructor has been successful in his prime mission; the indicated weaknesses are the points where additional emphasis and instructional time should be focused. The data presented in Table 34 pinpoints the specific items and tells how they were passed or failed by the students on an Air-Force-wide basis. Items which are failed by many students and which in the opinion of the instructors represent fundamental facts or concepts which should be understood by the average student should be taught more effectively next year.

Table 34

Percent of Students Passing Each of the Eighty Items on the Administration and Military Management Examination

100% to 91% Item No.	90% to 81% Item No.	80% to 71% Item No.	70% to 61% Item No.	60% to 51% Item No.	50% to 41% Item No.	40% to 31% Item No.	30% to 21% Item No.	20% to 11% Item No.	10% or less Item No.
11	1	2	3	6	4	12			
14	10	5	9	8	35	23			
17	15	7	13	31	50	63			
19	25	16	24	32	64	72			
26	28	18	27	33	75				
40	29	20	30	42	78				
62	39	21	36	43					
69	41	22	37	53					
	45	34	38	59					
	55	48	44	60					
	57	54	46	79					
	65	67	47						
	66	70	49						
	68	71	51						
	73	76	52						
			56						
			58						
			61						
			74						
			77						
			80						

About forty-five per cent (45) of the test items showed pass-per cents between sixty-one per cent (61%) to eighty per cent (80%). About nineteen per cent (19%) showed pass per cents between eighty-one per cent (81%) to ninety per cent (90%). There was a deficiency of items in the per cent categories of thirty per cent (30%) and below; yet eleven per cent (11%) of the items were in the category ninety-one per cent (91%) to one hundred per cent (100%).

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Attention might be drawn to these items were the pass-per cents are fifty per cent (50%) or less. Close scrutiny should be given this group of items as they may reveal student weak spots and indicate to the instructor the curricular sub-topics where instruction is needed or where superior instruction should be offered in subsequent lesson periods.

Aircraft Maintenance Examination

This examination consisted of eighty (80) multiple-choice items designed to measure student understanding of aircraft maintenance engineering principles and procedures. The papers of four hundred (400) students were studied in this analysis.

Test items were analyzed for their discriminating power, that is, their power to differentiate good students from poor students. Good discriminating power is indicated by positive validity coefficients and poor discriminating power is indicated by negative validity coefficients. Validity coefficients may range from -1.00 to 0 to +1.00. A valid test should contain items whose validity coefficients are at least .25 or better. Fifty-six (56) of the items measured up to the standard of .25 or better for a discriminating item. The average validity coefficient for all items was .32, a little higher than the average of .29 on a similar test given last year.

Test items were analyzed for their difficulty (per cent right). The average difficulty was seventy-three per cent (73%). This test was easier than a similar test administered last year, which had an average difficulty of sixty-four per cent (64%). The average difficulty is the average of the pass per cents of the eighty (80) items. The number of items of a specified difficulty is as follows:

	Difficulty (Per cent Right)			
	50% and Below	51% to 90%	91% to 100%	Total Test
Number of Items	8	63	9	80

Test items were analyzed for their discriminating power. Alternative A in Items 2 and 10, Alternative C in Item 25, Alternative B in Item 28, Alternative E in Item 30, and Alternative A in Items 66 and 73 drew no responses at all. These alternatives are evidently not plausible and should be replaced by new alternatives.

The following items had alternatives which misled a disproportionate number of the better students. These alternatives should be reviewed with a view to revision.

Item	Alternative	Item	Alternative
1	E	39	E
4	A	42	B
6	E	45	E
8	C	46	D
12	A	49	B
14	A,B	54	E
17	C	55	E
18	C	62	C
20	E	63	E
25	B	70	A
30	B	75	C
31	A	76	A,C
35	B	79	D
36	B		

In order to obtain a quick overview as to which items were excellent, very good, good, fair and poor, a distribution of the eighty (80) items according to the degree of validity coefficient was made and is presented in Table 35.

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Table 35

Validity of Coefficients of the Eighty Items of the Aircraft Maintenance Examination

Coefficients .14 and below (Poor)	Coefficients .15 to .24 (Fair)	Coefficients .25 to .34 (Good)	Coefficients .35 to .44 (Very Good)	Coefficients .45 and above (Excellent)
Item No.	Item No.	Item No.	Item No.	Item No.
12, 17, 20, 22, 26, 30, 31	2, 4, 8, 18, 21, 25, 27, 29, 32, 36, 38, 39, 42, 46, 47, 51, 56	9, 11, 13, 24, 28, 33, 34, 35, 41, 45, 48, 50, 52, 53, 55, 62, 63, 66, 68, 69, 71, 76, 79	1, 3, 6, 7, 10, 14, 16, 19, 37, 40, 43, 49, 54, 57, 61, 64, 67, 74, 75, 77	5, 15, 23, 44, 58, 59, 60, 65, 70, 72, 73, 78, 80

The number and the per cent of the items in each of the five (5) categories is as follows:

Category	Number of Items	Per cent of Total (80)
Excellent	13	16%
Very Good	20	25%
Good	23	29%
Fair	17	21%
Poor	7	9%

About sixteen per cent (16%) of the items are excellent; in all about seventy per cent (70%) of the items have a rating of good or better.

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The analysis of the items as to validity coefficient is an important one to make for the instructor as an examiner. However, an equally significant analysis of the items from the point of view of the instructor as a teacher is the one that reveals the specific strengths and weaknesses of the students. The indicated strengths reflect areas where the instructors have been successful in their prime mission; the indicated weaknesses are the points where additional emphasis and instructional time should be focused. The following analysis in Table 36 pinpoints the specific items and tells how they were passed or failed by the students on an Air Force-wide basis. Items which are failed by many students and which in the opinion of the instructors represent fundamental facts or concepts which should be understood by the average student should be taught more effectively next year.

Table 36

Per cent of Students Passing Each of the Eighty Items of the Aircraft Maintenance Examination

100% to 91% Item No.	90% to 81% Item No.		80% to 71% Item No.		70% to 61% Item No.	60% to 51% Item No.	50% to 41% Item No.	40% to 31% Item No.	30% to 21% Item No.	20% to 11% Item No.	10% or Less Item No.
2	12	57	4	56	1	14	13	3	6		
17	18	61	5	64	7	16	37	15			
25	21	66	9	67	8	24	45	70			
26	27	74	19	69	10	55		79			
31	30	75	22	71	11	63					
38	34		23	76	44	65					
48	35		28	77	53	78					
52	36		29		54						
	39		32		58						
	41		33		59						
	42		40		60						
	46		43		62						
	50		47		68						
	51		49		72						
					80						

About forty-four per cent (44%) of the test items showed pass-per cents between sixty-one per cent (61%) and eighty per cent (80%). About twenty-five per cent (25%) showed pass-per cents between eighty-one per cent (81%) and ninety per cent (90%). There was a deficiency of items in the per cent categories of fifty per cent (50% and below; yet eleven per cent (11%) of the items were in the category ninety-one per cent (91%) to one hundred per cent (100%).

Attention might be drawn to those items where the pass-per cents are fifty per cent (50%) or less. Close scrutiny should be given this group of items as they may reveal student weak spots and indicate to the instructor the curricular sub-topics where instruction is needed or where superior instruction should be offered in subsequent lesson periods.

Armament Examination

This examination consisted of eighty (80) multiple-choice items designed to measure student knowledge of technical details and their understanding of principles used in Armament work. For this analysis, 150 student papers were separated into 5 ability groups, using total score as the criterion.

Test items were analyzed for their discriminating power, that is, their power to differentiate good students from poor students. Good discriminating power is indicated by positive validity coefficients and poor discriminating power is indicated by negative validity coefficients. Validity coefficients may range from -1.00 to 0 to +1.00. A valid test should contain items whose validity coefficients are at least .25

or better. Sixty-nine (69) of the 80 items measure up to the standard of .25 or better for a discriminating item. The average validity coefficient for all test items was .45 compared with an index of .22 for a similar test which was administered last year. This represents a considerable improvement in the discriminating power of the test.

Test items were also analyzed for difficulty. The average difficulty of items on this test was 72 per cent correct compared with an average difficulty of 67 per cent correct for items of a similar test administered one year ago. The average per cent difficulty is the average of the pass per cents of the 80 items. The number of items of a specified difficulty is as follows:

	Difficulty (per cent right)			
	50% and Below	51% to 90%	91% to 100%	Total Test
Number of Items	6	62	12	80

Test items were analyzed for their discriminating power. Most of the items were quite effective in discriminating between able and less able students; however, a detailed analysis of test items shows a number of ineffective alternatives which might well be replaced by more plausible distractors. The following alternatives should be replaced, as they were chosen more frequently by good students than by poor ones:

Item	Alternative	Item	Alternative
11	E	40	A, C
30	B	42	D
36	D	56	B
37	E	60	A, C

In order to obtain a quick overview as to which items were excellent, very good, good, fair and poor, a distribution of 80 items according to the degree of validity coefficient was made and is given in Table 37A.

Table 37A

Validity Coefficients of the Eighty Items
of the Armament Examination

Coefficients .14 and below (Poor)	Coefficients .15 to .24 (Fair)	Coefficients .25 to .34 (Good)	Coefficients .35 to .44 (Very Good)	Coefficients .45 and above (Excellent)	
Item No.	Item No.	Item No.	Item No.	Item No.	
19	33	3	4	1	32
24	44	9	11	2	35
41	46	37	13	5	42
	47	38	22	6	51
	48	43	23	7	56
	50	49	26	8	58
	54	52	34	10	59
	57	53	36	12	61
		73	39	14	62
		78	40	15	64
			45	16	68
			55	17	69
			60	18	70
			63	20	71
			65	21	72
			66	25	74
			67	27	75
			80	28	76
				29	77
				30	79
				31	

The number and the per cent of the items in each of the five categories is as follows:

Category	No. of Items	Per cent of Total (80)
Excellent	41	51%
Very Good	18	22%
Good	10	13%
Fair	8	10%
Poor	3	4%

About fifty-one per cent (51%) of the items are excellent; in all about eighty-six per cent (86%) of the items have a rating of good or better.

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The analysis of the items as to validity coefficient is an important one to make for the instructor as an examiner. However, an equally significant analysis of the items from the point of view of the instructor as a teacher is the one that reveals the specific strengths and weaknesses of the students. The indicated strengths reflect areas where the instructor has been successful in his prime mission; the indicated weaknesses are the points where additional emphasis and instructional time should be focused. The following analysis in Table 37B pinpoints the specific items and tells how they were passed or failed by the students on an Air-Force-wide basis. Items which are failed by many students and which in the opinion of the instructors represent fundamental facts or concepts which should be understood by the average student, should be taught more effectively next year.

Table 37B

Per cent of Students Passing Each of the 80 Items on the Armament Examination

100% to 91% Item No.	90% to 81% Item No.	80% to 71% Item No.	70% to 61% Item No.		60% to 51% Item No.	50% to 41% Item No.	40% to 31% Item No.	30% to 21% Item No.	20% to 11% Item No.	10% or Less Item No.
5	9	1	2	59	16	21	42	60		
13	12	4	3	61	23	40				
19	15	8	6	68	30	54				
41	17	14	7	74	31	67				
44	24	20	10	80	35					
46	27	26	11		36					
47	34	33	18		56					
48	38	37	22		63					
50	43	51	25		70					
52	45	62	28							
73	49	64	29							
79	55	69	32							
	57	71	39							
	65	72	53							
	66	75	58			77				
	78	76								
		77								

About forty-six per cent (46%) of the test items showed pass-per cents between 61% and 80%. About 20% showed pass-per cents between 81% to 90%.

There was a deficiency of items in the per cent categories of 40% and below; yet 15% of the items were in the category 91% to 100%.

Attention might be drawn to those items where the pass-per cents are 50% or less. Close scrutiny should be given this group of items as they may reveal student weak spots and indicate to the instructor the curricular sub-topics where instruction is needed or where superior instruction should be offered in subsequent lesson periods.

Communications Examination

This examination was made up of eighty (80) multiple-choice items designed to measure student knowledge of technical communications information. The test papers of two hundred and ten (210) students were studied in this analysis.

Test items were analyzed for their discriminating power, that is, their power to differentiate good students from poor students. Good discriminating power is indicated by positive validity coefficients and poor discriminating power is indicated by negative validity coefficients. Validity coefficients may range from -1.00 to 0 to +1.00. A valid test should contain items whose validity coefficients are at least .25 or better. Sixty-one (61) items measured up to the standard of .25 or better for a discriminating item. The average validity coefficient for all test items was .35 compared with an index of .31 on a similar test given last year. This represents a definite improvement in the test.

This year's test was much easier than a similar test administered last year. The difficulty of the test was seventy-one per cent (71%). The average per cent difficulty is the average of the pass-per cents of the eighty (80) items. The number of items of a specified difficulty is as follows:

	Difficulty (Per Cent Right) 50% and below	51% to 90%	91% to 100%	Total Test
Number of Items	12	61	7	80

Test items were analyzed for their discriminating power. Items 2, 3, 40, 45 and 69 were extremely easy and might be replaced by better items. Most of the remaining items had effective alternatives; however, a study of the detailed analysis of test items will reveal other weak alternatives.

The following items had alternatives which were chosen more frequently by good students than by poor ones. These alternatives should be reviewed carefully and revised or replaced:

Item	Alternative	Item	Alternative
1	E	51	C
10	D	56	A
14	B	58	D
17	C	62	D
36	E	65	B
38	C	68	C
39	B	77	B
42	A	78	A
43	C, E	80	C

Items 2, 8, 40, 45 and 69 were extremely easy and might be replaced by better items. Most of the remaining items had effective alternatives.

In order to obtain a quick overview as to which items were excellent, very good, good, fair and poor, a distribution of eighty (80) items according to the degree of validity coefficient was made and given in Table 38.

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Table 38

Validity Coefficients of the Eighty Items of the Communications Examination

Coefficients .14 and below (Poor) Item No.	Coefficients .15 to .24 (Fair) Item No.	Coefficients .25 to .34 (Good) Item No.	Coefficients .35 to .44 (Very Good) Item No.		Coefficients .45 and above (Excellent) Item No.
2	3	4	1	31	6
8	20	9	5	35	7
40	24	12	10	41	11
45	43	16	14	47	13
56	48	23	17	49	15
58	62	36	18	61	27
68	67	38	19	63	28
69	70	39	21	64	32
	72	44	22	66	33
	78	52	25	71	34
	80	54	26	74	37
		60	29	79	42
		65	30		46
		73			50
		75			51
		76			53
					55
					57
					59
					77

The number and the per cent of the items in each of the five categories are as follows:

Category	Number of Items	Per Cent of Total (80)
Excellent	20	25%
Very Good	25	31%
Good	16	20%
Fair	11	14%
Poor	8	10%

About twenty-five per cent (25%) of the items are excellent; in all about seventy-six per cent (76%) of the items have a rating of good or better.

The analysis of the items as to validity coefficient is an important one to make for the instructor as an examiner. However, an equally

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significant analysis of the items from the point of view of the instructor as a teacher is the one that reveals the specific strengths and weaknesses of the students. The indicated strengths reflect areas where the instructor has been successful in his prime mission; the indicated weaknesses are the points where additional emphasis and instructional time should be focused. The data presented in Table 39 pinpoints the specific items and tells how they were passed or failed by the students on an Air-Force-wide basis. Items which are failed by many students and which in the opinion of the instructors represent fundamental facts or concepts which should be understood by the average student should be taught more effectively next year.

Table 39

Per Cent of Students Passing Each of the Eighty Items of the Communications Examination

100% to 91% Item No.	90% to 81% Item No.	80% to 71% Item No.		70% to 61% Item No.	60% to 51% Item No.	50% to 41% Item No.	40% to 31% Item No.	30% to 21% Item No.	20% to 11% Item No.	10% or less Item No.
2	4	1	46	7	13	6	78	51		
8	16	3	49	10	15	17				
40	23	5	50	11	18	19				
45	24	9	56	21	27	31				
48	35	12	63	22	34	33				
68	41	14	67	25	42	37				
69	52	20	71	29	47	43				
79	54	26	74	44	57	55				
	60	28	75	53		73				
	62	30		58		77				
	65	32		59						
	72	36		61						
	76	38		64						
	80	39		66						
				70						

About forty-eight per cent (48%) of the test items showed pass per cents between sixty-one per cent (61%) and eighty per cent (80%). About nineteen per cent (19%) showed pass-per cents between eighty-one (81%) and ninety per cent (90%). There was a deficiency of items in the per cent categories of forty per cent (40%) and below; yet nine per cent (9%) of the items were in the category ninety-one per cent (91%) to one hundred per cent (100%).

Attention might be drawn to those items where the pass-per cents are fifty per cent (50%) or less. Close scrutiny should be given this group of items as they may reveal student weak spots and indicate to the instructor the curricular sub-topics where instruction is needed or where superior instruction should be offered in subsequent lesson periods.

Introduction to USAF Examination

This examination consisted of eighty multiple-choice items designed to measure student understanding of several topics included in this course. A sample of four hundred (400) student papers were used in the analysis. These papers were separated into five ability groups, using total score as the criterion.

Test items were analyzed for their discriminating power, that is, their power to differentiate good students from poor students. Good discriminating power is indicated by positive validity coefficients and poor discriminating power is indicated by negative validity coefficients. Validity coefficients may range from -1.00 to 0 to +100.

A valid test should contain items whose validity coefficients are at least .25 or better. Seventy-six of the 80 items measured up to the standard of .25 or better for a discriminating item. The average validity coefficient for all test items was .45, an extremely high figure and was slightly higher than the figure reported for a similar test last year.

This year's test items had an average difficulty of 67 per cent correct compared with an average difficulty of 53 per cent correct for a similar test which was administered last year. This probably indicates that the test this year was slightly easier than last year's. The number of items of a specified difficulty is as follows:

	Difficulty (Per cent right)			
	50% and below	51% to 90%	91% to 100%	Total Test
Number of Items	13	61	6	80

Of the 80 items, there were only 7 items which were passed by 90 to 100 per cent of the students.

The following items had alternatives which were chosen more frequently by good students than by poor ones. These alternatives should be reviewed carefully and possibly revised.

Item	Alternative	Item	Alternative
3	B	52	E
10	D	64	C
23	D	65	D
24	[illegible]	66	E
25	D	68	A
46	C, D	73	A
47	D	75	E

An effort should be made to secure alternatives for each item which serve as effective distractors. Most of the items have effective alternatives.

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In order to obtain a quick overview as to which items were excellent, very good, good, fair and poor, a distribution of eighty items according to the degree of validity coefficient was made and is given in Table 40.

Table 40

Validity Coefficients of the Eighty Items on the Introduction to USAF Examination

Coefficients .14 and below (Poor) Item No.	Coefficients .15 to .24 (Fair) Item No.	Coefficients .25 to .34 (Good) Item No.	Coefficients .35 to .44 (Very Good) Item No.	Coefficients .45 and above (Excellent) Item No.	
36	1	3	9	2	51
	12	4	14	5	52
	30	17	16	6	53
		19	18	7	54
		25	21	8	56
		31	22	10	57
		38	24	11	60
		46	29	13	62
		47	34	15	63
		66	35	20	64
			37	23	65
			39	26	68
			45	27	69
			55	28	70
			58	32	71
			59	33	72
			61	40	73
			67	41	74
				42	75
				43	76
				44	77
				48	78
				49	79
				50	80

The number and per cent of items in each category is as follows:

Category	No. of Items	Per Cent of Total (80)
Excellent	48	60%
Very Good	18	23%
Good	10	12%
Fair	3	4%
Poor	1	1%

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About sixty per cent of the items are excellent; in all about 95 per cent of the items have a rating of good or better.

The analysis of the items as to validity coefficients is an important one to make for the instructor as an examiner. However, an equally significant analysis of the items from the point of view of the instructor as a teacher is one that reveals the specific strengths and weaknesses of the students. The indicated strengths reflect the areas where the instructor has been successful in his prime mission; the indicated weaknesses are the points where additional emphasis and instructional time should be focused. The following tabular analysis pinpoints the specific items and tells how they were passed or failed by the students on an Air-Force-wide basis. Items which are failed by many students and which in the opinion of the instructors represent fundamental facts or concepts which should be understood by the average student should be taught more effectively next year. See Table 41.

Table 41

Per Cent of Students Passing Each of the Eighty Items on the Introduction to USAF Examination

100% to 91% Item No.	90% to 81% Item No.	80% to 71% Item No.		70% to 61% Item No.		60% to 51% Item No.	50% to 41% Item No.	40% to 31% Item No.	30% to 21% Item No.	20% to 11% Item No.	10% or Less Item No.
1	3	8	44	2	60	11	5	53	10	45	
4	14	9	52	7	61	27	6		23		
12	17	15	55	21	62	32	13		37		
30	18	19	65	24	63	48	16		46		
36	22	20	66	33	69	57	50		64		
59	25	26	68	34	70	67	51				
	31	28	73	35	77	72	53				
	38	29	74	39	79	76					
	47	41	75	40	80						
	56	42	78	49							
	71	43		54							

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About 51 per cent of the items showed pass per cents of between 61% to 80%. One item had a pass-per cent between 31% to 40% and one item had a pass per cent of between 11% to 20%. No items received pass-per cents of 10% or less; however, there were six items that had pass-per cents of 19% to 100%.

Attention should be drawn to those items where the pass per cents is 50% or less. Close scrutiny should be given to this group of items as they may reveal students weak spots and indicate to the instructor the curricular sub-areas where instruction is needed or where superior instruction should be offered in subsequent lesson periods.

Statistical Control Examination

This examination was made up of eighty (80) multiple-choice items designed to measure student understanding of the principles and procedures of Statistical Control. The papers of two hundred thirty-five (235) students were used for this analysis.

Test items were analyzed for their discriminating power, that is, their power to differentiate good students from poor students. Good discriminating power is indicated by positive validity coefficients and poor discriminating power is indicated by negative validity coefficients. Validity coefficients may range from -1.00 to 0 to /1.00. A valid test should contain items whose validity coefficients are at least .25 or better. The average validity coefficient for all items was .23, a lower figure than the average of .26 for a similar test given last year. There were thirty-six (36) items which met the standard of .25 or better for a discriminating item.

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The test items were analyzed for their difficulty, that is, their per cent right. The average difficulty was seventy per cent (70%). This test was of approximately the same difficulty as a test on the same subject administered last year, which had an average difficulty of sixty-eight per cent (68%). The average per cent difficulty is the average of the pass-per cents of the eighty (80) items. The number of items of a specified difficulty is as follows:

	Difficulty (Per cent Right)			
	50% and Below	51% to 90%	91% to 100%	Total Test
Number of Items	10	60	10	80

Test items were analyzed for their discriminating power. There were several items (with validity coefficients less than .25) in which incorrect alternatives drew no student responses. These alternatives, which are listed below, are evidently not plausible and should be replaced with new alternatives.

Item	Alternative	Item	Alternative
9	D	39	D
19	C, E	40	C, E
22	C	46	A, B
28	E	47	E
35	D, E	51	C
37	D	68	D
38	C, D		

Several items such as , 22, 23, 25, 26, 34, 37, 38, 40, 42 and 52 might well be replaced by better items. In the case of the following items, the incorrect alternatives indicated misled a disproportionate number of the better students. These alternatives should be reviewed for revision or replacement.

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Item	Alternative	Item	Alternative
1	C, D	39	C
4	E	41	A
5	D	42	A, D
7	B	43	B
8	A, E	45	B, D
9	A	49	E
11	C	51	A, B
12	C, D	52	D
13	B	56	A
15	A	66	C
16	E	68	B
17	D	70	D
18	D	71	A, E
21	B	72	C, D
25	D, E	73	E
26	D, E	74	A, B
29	E	75	E
33	B, C	76	E
34	B	77	D
35	C	80	D
37	E		

It is felt that this examination was of appropriate difficulty but its discriminating power was low. The other seven (7) examinations had high discriminating power and were of approrpiate difficulty.

In order to obtain a quick overview as to which items were excellent, very good, good, fair and poor, a distribution of the eighty (80) items according to the degree of validity coefficient was made and given in Table 42.

Table 42

Validity Coefficients of the Eighty Items
of the Statistical Control Examination

Coefficients .14 and below (Poor) Item No.	Coefficients .15 to .24 (Fair) Item No.		Coefficients .25 to .34 (Good) Item No.		Coefficients .35 to .44 (Very Good) Item No.	Coefficients .45 and above (Excellent) Item No.
7	1	51	5	66	3	57
8 (-.07)	2	54	6	67	4	65
16	9	56	12	69	17	
22	10	73	13	71	20	
23	11	74	14	72	41	
24	15	75	18	80	55	
25	19	76	21		59	
26	27	77	29		62	
31	28		30		64	
34	32		36		78	
37	33		44		79	
38	35		49			
40	39		53			
42	45		58			
43	46		60			
48	47		61			
52	50		63			

The number and the per cent of the items in each of the five (5) categories is as follows:

Category	Number of Items	Per cent of Total (80)
Excellent	2	2%
Very Good	11	14%
Good	23	29%
Fair	27	34%
Poor	17	21%

About two per cent (2%) of the items are excellent; in all about forty-five per cent (45) have a rating of good or better.

The analysis of the items as to validity coefficient is an important one to make for the instructor as an examiner. However, an equally significant analysis of the items from the point of view of the instructor as a teacher is the one that reveals the specific strengths and weaknesses of the students. The indicated strengths reflect areas where the instructor has been successful in his prime mission; the indicated weaknesses are the points where additional emphasis and instructional time should be focused. The data of Table 43 pinpoints the specific items and tells how they were passed or failed by the students on an Air-Force-wide basis.

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Table 43

Per cent of Students Passing Each of the Eighty Items on the Statistical Control Examination

100% to 91% Item No.	90% to 81% Item No.	80% to 71% Item No.	70% to 61% Item No.	60% to 51% Item No.	50% to 41% Item No.	40% to 31% Item No.	30% to 21% Item No.	20% to 11% Item No.	10% or less Item No.
8	2	1	3	13	23	4		32	
19	10	5	12	26	39	25			
38	37	6	14	40	54	75			
43	47	7	15	41	61				
46	50	9	16	42	70				
48	57	11	17	45					
51	62	18	24	55					
52	63	20	28	58					
56	73	21	44	59					
67	76	22	49	64					
	77	27	60	66					
	79	29	65	72					
	80	30	69						
		31	74						
		33	78						
		34							
		35							
		36							
		53							
		71							

Items which are failed by many students and which in the opinion of the instructors represent fundamental facts or concepts which should be understood by the average student should be taught more effectively next year.

About forty-four per cent (44%) of the test items showed pass-per cents between sixty-one per cent (61%) and eighty per cent (80%). About eighteen per cent (18%) showed per cents between eighty-one per cent (81%) and ninety per cent (90%).

There was a deficiency of items in the per cent categories of fifty per cent (50%) and below; yet twelve (12%) of the items were in the category ninety-one per cent (91%) to one hundred per cent (100%).

Attention might be drawn to those items where the pass per cents are fifty per cent (50%) or less. Close scrutiny should be given this group of items as they may reveal student weak spots and indicate to the instructor the curricular sub-topics where instruction is needed or where superior instruction should be offered in subsequent lesson periods.

Supply Examination

This examination consisted of eighty (80) multiple-choice items designed to measure student understanding of supply procodures. The test papers of two hundred and sixty (260) students were studied in this analysis.

Test items were analyzed for their discriminating power, that is, their power to differentiate good students from poor students. Good discriminating power is indicated by positive validity coefficients and poor discriminating power is indicated by negative validity coefficients. Validity coefficients may range from -1.00 to 0 to +1.00. A valid test should contain items whose validity coefficients are at least .25 or better. Forty-eight (48) of the eighty (80) items measured up to the standard of .25 or better for a discriminating item. The average validity coefficient for all test items was .31, slightly higher than the average of .29 on a similar test administered last year.

This year's test was much easier than a similar test administered last year. The difficulty of the test was seventy-one per cent (71%) correct compared with a difficulty of fifty-seven per cent (57%) correct for last year's test. The average per cent difficulty is the average of the pass-per cents of the eighty (80) items. The number of items of a specified difficulty is as follows:

	Difficulty (Per cent Right)			
	50% and Below	51% to 90%	91% to 100%	Total Test
Number of Items	15	57	8	80

Test items were analyzed for their discriminating power. There were two items, 2 and 62, which were missed more frequently by good students than by poor ones, hence they had negative validity coefficients. These items should be reviewed and revised.

The following alternatives found in items with low discriminating power drew no response and are recommended for replacement:

Item	Alternative	Item	Alternative
1	D	35	D
11	A	55	A
12	E	58	E
32	C, E	75	D, E

The following items had alternatives which were chosen more frequently by good students than by poor ones. These alternatives which were chosen more frequently by good students than by poor ones should be reviewed and revised or replaced.

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Item	Alternative	Item	Alternative
2	D, E	34	A
8	D	40	A
11	D	41	B
12	D	53	A
14	B	54	B, E
17	D	55	E
18	E	58	B
24	D	59	D
25	D	62	A, C, D
27	C, D	69	C
28	C	72	D
29	E	74	D
32	D	78	D
33	E	79	B

In order to obtain a quick overview as to which items were excellent, very good, good, fair and poor, a distribution of eighty (80) items according to the degree of validity coefficient was made and given in Table 44.

Table 44

Validity Coefficients of the Eighty Items of the Supply Examination

Coefficients .14 and below (Poor) Item No.	Coefficients .15 to .24 (Fair) Item No.		Coefficients .25 to .34 (Good) Item No.		Coefficients .35 to .44 (Very Good) Item No.	Coefficients .45 and above (Excellent) Item No.
1	8	45	3	56	4	5
2(-.05)	12	51	11	59	7	6
9	14	52	16	65	18	10
15	21	54	17	70	19	13
24	22	55	23	72	20	28
41	25	69	26	78	27	31
46	29	71	33	79	30	42
48	32	73	35		49	47
58	34	74	37		50	60
62 (-.04)	36	75	39		53	63
	38		43		57	64
	40		44		61	66
					68	67
					76	77
						80

The number and the per cent of the items in each of the five (5) categories is as follows:

Category	Number of Items	Per cent of Total (80)
Excellent	15	19%
Very Good	14	17%
Good	19	24%
Fair	22	28%
Poor	10	12%

About nineteen per cent (19%) of the items are excellent; in all about sixty per cent (60%) of the items have a rating of good or better.

The analysis of the items as to validity coefficient is an important one to make for the instructor as an examiner. However, an equally significant analysis of the items from the point of view of the instructor as a teacher is the one that reveals the specific strengths and weaknesses of the students. The indicated strengths reflect areas where the instructor has been successful in his prime mission; the indicated weaknesses are the points where additional emphasis and instructional time should be focused. The date in Table 45 pinpoints the specific items and tells how they were passed or failed by the students on an Air-Force-wide basis. Items which are failed by many students and which in the opinion of the instructors represent fundamental facts or concepts which should be understood by the average student should be taught more effectively next year.

Table 45

Per Cent of Students Passing Each of the Eighty Items of the Supply Examination

100% to 91% Item No.	90% to 81% Item No.	80% to 71% Item No.	70% to 61% Item No.	60% to 51% Item No.	50% to 41% Item No.	40% to 31% Item No.	30% to 21% Item No.	20% to 11% Item No.	10% or Less Item No.
15	1	4	2	5	7	17			
21	3	9	6	10	8	53			
25	11	13	18	27	19	58			
34	12	14	31	40	28				
35	16	23	45	42	36				
41	20	24	47	49	50				
46	22	33	51	60	54				
48	26	43	66	61	59				
	29	56	67	62	63				
	30	64	69	79	73				
	32	68			80				
	37	71							
	38	78							
	39								
	44								
	52								
	55								
	57								
	65								
	70								
	72								
	74								
	75								
	76								
	77								

About twenty-eight per cent (28%) of the test items showed pass-per cents between sixty-one per cent (61%) and eighty per cent (80%). About thirty-one per cent (31%) showed pass-per cents between eighty-one per cent (81%) to ninety per cent (90%). There was a deficiency of items in the per cent categories of forty per cent (40%) and below; yet ten per cent (10%) of the items were in the category ninety-one per cent (91%) to one hundred per cent (100%).

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Attention might be drawn to those items where the pass-per cents are fifty per cent (50%) or less. Close scrutiny should be given this group of items as they may reveal student weak spots and indicate to the instructor the curricular sub-topics where instruction is needed or where superior instruction should be offered in subsequent lesson periods.

Transportation Examination

This examination consisted of eighty (80) multiple-choice items designed to measure student knowledge of Transportation procedures. A sample of 190 student papers were used in this analysis. These papers were separated into five (5) ability groups, using total score as the criterion. Tests items were analyzed for their discriminating power, that is, their power to differentiate good students from poor students. Good discriminating power is indicated by positive validity coefficients and poor discriminating power is indicated by negative validity coefficients. Validity coefficients may range from -1.00 to 0 to ≠1.00. A valid test should contain items whose validity coefficients are at least .25 or better. Sixty-three (63) items had a validity coefficient of .25 (standard) or better. The average validity coefficient was .40, as compared to an average of .25 for last year. Three items (27, 31 and 37) had negative validity coefficients, that is, they were answered correctly by a greater number of poor students than good students.

This year's test items had an average difficulty of sixty-eight per cent (68%), the same as for a similar test administered last year. The average per cent difficulty is the average of the pass-per cents of the eighty (80) items. The number of items of a specified difficulty

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is as follows:

	Difficulty (Per cent right)			
	50% and below	51% to 90%	91% to 100%	Total Test
Number of Items	11	66	3	80

Of the eighty (80) items there were only four (4) items which were passed by ninety to one hundred per cent (90-100%) of the students.

The alternatives listed below misled a disproportionate number of the better students. These alternatives should be studied for revision before the next administration of this examination.

Item	Alternative	Item	Alternative
2	C	44	E
5	C	45	D
10	B	48	A, E
15	B	49	A
21	A	51	E
25	B, E	52	C, D
27	C	54	D
30	E	65	C
31	B	67	A
35	E	68	A
37	B, E	69	E
39	E	72	D
41	A	73	A
42	D	78	A, C

In order to obtain a quick overview as to which items were excellent, very good, good, fair, and poor, a distribution of eighty (80) items according to the degree of validity coefficient was made and is given in Table 46.

Table 46

Validity Coefficients of the Eighty Items on the Transportation Examination

Coefficients .14 and below (Poor) Item No.	Coefficients .15 to .24 (Fair) Item No.	Coefficients .25 to .34 (Good) Item No.	Coefficients .35 to .44 (Very Good) Item No.	Coefficients .45 and above (Excellent) Item No.	
21	10	17	1	2	51
27 (-.01)	15	19	8	3	54
31 (-.01)	25	22	11	4	55
37 (-.03)	41	24	14	5	59
39	42	29	18	6	60
44	46	30	34	7	64
48	57	40	52	9	65
72	73	43	53	12	66
	78	47	58	13	68
		50	62	16	69
		56	67	20	70
		61	71	23	74
		63		26	75
				28	76
				32	77
				33	79
				35	80
				36	
				38	
				45	
				49	

The number and per cent of the items in each of the five (5) categories is as follows:

Category	Number of Items	Per Cent of Total (80)
Excellent	38	48%
Very Good	12	15%
Good	13	16%
Fair	9	11%
Poor	8	10%

About forty-eight per cent (48%) of the items are excellent, in all about seventy-nine per cent (79%) of the items have a rating of good or better.

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The analysis of the items as to validity coefficients is an important one to make for the instructor as an examiner. However, an equally significant analysis of the items from the point of view of the instructor as a teacher is one that reveals the specific strengths and weaknesses of the students. The indicated strengths reflect the areas where the instructor has been successful in his prime mission. The indicated weaknesses are the points where additional emphasis and instructional time should be focused. The data presented in Table 47 pinpoints the specific items and tells how they were passed or failed by the students on an Air Force-wide basis. Items which are failed by many students and which in the opinion of the instructors represent fundamental facts or concepts which should be understood by the average student should be taught more effectively next year.

Table 47

Per Cent of Students Passing Each of the Eighty Items on the Transportation Examination

100% to 91% Item No.	90% to 81% Item No.		80% to 71% Item No.	70% to 61% Item No.	60% to 51% Item No.	50% to 41% Item No.	40% to 31% Item No.	30% to 21% Item No.	20% to 11% Item No.	10% or Less Item No.
31	1	57	2	9	5	3	22	54		
44	8	58	4	13	6	7	32			
61	10	62	11	15	16	28	49			
	19	72	12	23	20	34	68			
	24	73	14	36	26	78	77			
	25		17	45	30					
	27		18	51	33					
	37		21	52	50					
	39		29	53	55					
	40		35	59	63					
	41		38	66	64					
	42		43	67	65					
	46		60	69	70					
	47		75	71	74					
	48			79	76					
	56			80						

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About fifty-six per cent (56%) of the items showed pass per cents between sixty-one per cent (61%) to eighty per cent (80%). About twenty-six per cent (26%) showed pass per cents between eighty-one per cent (81%) and ninety per cent (90%). There was a deficiency of items from thirty per cent (30%) and below.

Attention might be drawn to those items where the pass per cents are fifty per cent (50%) or less. Close scrutiny should be given this group of items as they may reveal student weak spots and indicate to the instructor the curricular sub-topics where instruction is needed or where superior instruction should be offered in subsequent lesson periods.

CHAPTER V

RESULTS OF THE AIR ROTC QUALIFYING EXAMINATION RQ-3-1949

Nature and Uses of the ROTC RQ-3 Test

The ROTC RQ-3 examination is one of the common verbal type tests for the measurement of general learning ability or of scholastic aptitude. This examination is divided into two parts, Part I, Language and Part II, Mathematics.

The RQ-3 examination was administered to each First Year Basic AF ROTC student during the academic year 1948-49. The test results afford an overall estimate of the general level of the learning caliber of the student at the various AF ROTC schools. There are several benefits that accrue as a result of the administration of RQ-3 test:

1. In a general way it affords an objective and scientific means of making a check inventory of a critical requirement of all potential officers--superior mental ability.
2. The test may be utilized as one method of measuring the extent to which students are attaining achievement on course examinations approximately commensurate with their mental alertness.
3. In the event the RQ-3 or an equivalent form of this test is given annually essential and necessary comparisons can be made over the years as to the quality of students entering and remaining in the Air ROTC program. It will help to answer the question as to the caliber of students that are electing to take the Air ROTC courses. The results

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of this test can be used to answer the question as to whether better, equally capable or poorer students stay with the ROTC program and take the advanced courses of instruction when compared with the freshmen group of students.

4. The results of the RQ-3 test gives the instructor a rough estimate of the range, and level of learning ability of his students and therefore, where necessary he should reflect these facts by appropriate modifications in reference materials, visual aids, motivation, teaching methods and standards of expected achievement.

5. In the event that a similar type of scholastic learning ability test is administered at the first advanced course year, an adequate picture of the mental caliber of potential officer personnel can be obtained.

6. The test results of the RQ-3 examination can be utilized in certain special circumstances, for example, in the event of a sudden curtailment in funds when the number of students must be reduced, the better qualified students could be selected for training.

7. It is conceivable that the results of a mental ability test can be utilized as one measure, in conjunction with others, which may be used appropriately in selecting the type of initial assignment given the graduated student officer or for selection of officer graduates for special advanced training.

8. The results of the RQ-3 can be utilized in setting up acceptable standards of student attainment on each of the course examinations.

In summary, while the results of the ROTC RQ-3 examination may be utilized in valuable ways, several qualifying statements need to be posited:

a. The results for groups such as mean standard scores for each school are more reliable than the scores for individual students.

b. Because of the very nature of a short group test of the RQ-3 type, the score of an individual student will be only a rough estimate of his general learning ability.

c. Other appraisals, ratings, and measures need to be employed in conjunction with mental test results in the overall evaluation of each individual student.

School Results on the RQ-3 Test

In order to obtain an indication of the mental caliber or scholastic aptitude of incoming ROTC students, a survey type test of intelligence, the ROTC RQ-3, was administered to 19,660 students in 112 schools throughout the United States. The results by air force and for all air forces combined are given in Table 48.

Table 48

Results of the ROTC Qualifying Examination for 112 AFROTC Schools 1948-49

Air Force	No. of Students	Mean Standard Measures	Relative Rank of Air Force
First Air Force	2218	135	1.0
Fourth Air Force	2865	125	4.0
Ninth Air Force	4940	127	2.5
Tenth Air Force	5420	127	2.5
Twelfth Air Force	2269	123	5.5
Fourteenth Air Force	1948	123	5.5
Total	19,660	127	

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The First Air Force with an average score of 135 achieved top rank.

A distribution of the mean standard scores of all participating Air ROTC schools was made. In addition, percentile rank equivalents of the mean standard scores were calculated. Percentile ranks are points in a series of scores below which lie a given percentage of the total number of schools. A percentile of fifty (50) means that the school attained a score below which approximately 50% of the school mean scores lie and above which the other 50% lie. A percentile of 99 is the highest or best percentile ranking and the first (1) percentile is the lowest or the poorest percentile ranking. The distribution of mean standard scores and percentile rankings for the 112 schools are given in Table 49. The left half part of Table 49 shows that the school averages on the RQ-3 test range from 107 to 145. Of the 112 schools, 97 of them or 87% attain mean scores between 119 and 133. With such wide variation in student scholastic aptitude one can reasonably expect wide range in achievement; and that in evaluating student course achievement at the various schools, one must seriously consider this differential in learning ability.

Table 49
Distribution of School Average Standard Scores and Selected Percentiles on the ROTC RQ-3 Examination

Distribution of Averages		Score Value of Percentiles	
School Average Scores	No.	Average Score	Percentile
143-145	1	144	99%
140-142	3		
137-139	4		
134-136	7	135	90%
131-133	10	131	80%
128-130	17	128	70%

Distribution of Averages		Score Value of Percentiles	
School Average Scores	No.	Average Score	Percentile
125-127	23	127	60%
		126	50%
		124	40%
122-124	28	123	30%
		122	20%
119-121	19	120	10%
116-118	5		
113-115	2		
110-112	0		
107-109	1	107	1%
Total	112		

Table 50 lists the RQ-3 mean standard scores of each of the schools participating in this testing survey. No norms or national standards for the RQ-3 test are currently available and at present the Air Force-wide medium of 126 (P_{50}) may be taken to represent the national norm. The RQ-3 tests results as shown in Table 50 will serve mainly to give a good description of the nature of the Air ROTC freshman student personnel. Subsequent systematized annual testings will afford data which can be organized and treated for optimum benefits to the Air ROTC programs as outlined in the opening paragraphs of this Chapter.

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TABLE 50

RESULTS OF ROTC QUALIFYING EXAMINATION RQ-3-1949

Air ROTC Freshmen - Academic Year 1948-49

Schools	No. of Students Examined	Mean Standard Score	Percentile Ranks of 112 Schools
ALL AIR FORCES	19,660	127	
FIRST AIR FORCE	2,218	135	
Trinity College	83	132	82
University of Conn.	247	130	77
Yale University	152	142	97
Boston University	156	130	77
Harvard University	65	139	80
Massachusetts Inst, of Tech,	98	141	96
University of Mass.	109	131	80
Williams College	103	138	93
University of New Hampshire	154	132	82
Rutgers University	216	134	88
Colgate University	103	134	88
Cornell University	271	138	93
Fordham University	201	131	80
New York University	197	134	88
Syracuse University	63	134	88
FOURTH AIR FORCE	2,865	125	
Arizona State College	60	121	15
University of Arizona	213	128	70
Fresno State College	51	123	30
Loyola Univ. of L.A.	148	123	30
San Jose State College	59	125	45
Stanford University	104	134	88
University of Calif. at L.A.	205	132	82
University of Southern California	37	126	50
University of Idaho	199	123	30
Montana State College	111	125	45
University of Nevada	91	124	40
Oregon State College	240	125	45
University of Oregon	293	125	45
Utah St. Ag. Coll.	238	119	9
Univ. of Utah	116	128	70
State Coll. of Wash.	251	122	20
University of Washington	318	126	50
Montana State University	131	128	70

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TABLE RESULTS OF ROTC RQ-3 EXAMINATION (cont'd)

Schools	No. of Students Examined	Mean Standard Score	Percentile Ranks of 112 Schools
NINTH AIR FORCE	4,040	127	
University of Kentucky	347	123	30
Western Kentucky State Tchrs.	66	118	9
Johns Hopkins University	120	135	90
University of Maryland	800	128	70
Ohio State University	940	123	30
Ohio University	279	121	15
Univ. of Akron	175	129	73
Univ. of Cincinnati	166	128	70
Duquesne University	193	121	15
Lehigh University	201	144	99
Penn. State College	450	129	73
University of Penns.	93	147	92
University of Pittsburgh	124	127	60
Virginia Military Inst.	71	124	40
Virginia Poly. Inst.	174	124	40
W. Virginia University	514	119	9
Georgetown University	74	128	70
Howard University	96	117	8
Gettysburg	57	130	77
TENTH AIR FORCE	5,420	127	
Colorado State Coll. of A&MA	271	122	20
University of Denver	25	122	20
Bradley University	107	125	45
University of Illinois	217	130	77
Ball St. Tchrs.Coll.	102	121	15
Butler University	57	123	30
Indiana University	478	125	45
Purdue University	266	133	66
University of Notre Dame	110	127	60
Coe College	79	125	45
Iowa State College	324	127	60
State University of Iowa	301	127	60
Kansas St. College	223	124	40
Univ. of Kansas	59	127	60
Univ. of Wichita	61	128	70
Washburn Municipal Univ.	63	124	40
College of St. Thomas	447	127	60
University of Minnesota	96	132	82
University of Minn. Duluth Br.	48	126	50
St. Louis University	272	141	96
Parks College	50	133	86
University of Missouri	194	123	30

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TABLE RESULTS OF ROTC RQ-3 EXAMINATION (Cont'd)

Schools	No. of Students Examined	Mean Standard Score	Percentile Ranks of 112 Schools
TENTH AIR FORCE (cont'd)			
University of Nebraska	303	125	45
N. Dakota Agr. Coll.	111	122	20
University of North Dakota	96	128	70
University of Wisconsin	225	128	70
Superior State Tchrs. College	84	119	9
University of Wyoming	113	124	40
Michigan Coll. of M & T	93	127	60
Michigan St. College of A & AS	282	126	50
University of Michigan	116	135	90
Wayne University	112	126	50
South Dakota St. Coll.	123	131	80
TWELFTH AIR FORCE	2,269	123	
University of Arkansas	161	120	10
Louisiana St. Univ.	222	122	20
Tulane University	86	126	50
Southwestern La. Inst.	220	115	7
New Mexico Coll. of A&MA	99	126	50
Oklahoma A & M	279	122	20
University of Oklahoma	307	126	50
A & M College of Texas	559	123	30
Baylor University	87	121	15
Southern Meth. Univ.	47	134	88
Texas Tech. College	119	120	10
University of Texas	83	124	40
FOURTEENTH AIR FORCE	1,948	122	
Alabama Poly. Inst.	172	120	10
Tuskegee Inst.	64	107	1
Univ. of Alabama	194	127	60
Univ. of Florida	504	123	30
Univ. of Miami	108	122	20
Ga. Inst. of Tech.	100	131	80
Univ. of Georgia	80	120	10
Miss. St. College	143	124	40
Univ. of Miss.	73	120	10
E. Carolina Tchrs. Coll.	38	116	8
N. Carolina St. Coll. of A&M	169	123	30
Univ. of N. Carolina	77	123	30
Clemson College	101	122	20
The Citadel	81	122	20
University of Tenn.	44	130	77

CHAPTER VI

APPROACHES TO THE EVALUATION OF THE EFFECTIVENESS OF INSTRUCTION

Purpose

An important question that may be raised is: Do the Air ROTC schools achieve rankings on the course examination commensurate with their relative ranks as achieved on the RQ-3 test? A comparison of the relative rankings among the air forces on the RQ-3 test, the Introduction to USAF and the Administration and Military Management Examinations is presented in Table 51.

TABLE 51

Relative Rankings Among the Six Air Forces on the ROTC RQ-3 Test, the Introduction to USAF and Administration and Military Management Examinations

Air Force	ROTC RQ-3 Test Relative Rank Among Air Forces	Introduction to USAF Examination Relative Rank Among Air Forces	Administration & Mil Management Relative Rank Among Air Forces
First Air Force	1	1	1
Fourth Air Force	4	3	2
Ninth Air Force	2.5	2	4
Tenth Air Force	2.5	4.5	3
Twelfth Air Force	5.5	6	6
Fourteenth Air Force	5.5	4.5	5

In general, there seems to be some relationship between the three sets of rankings. The First Air Force has a ranking of 1 on all three tests; the Twelfth and Fourteenth Air Forces are low or lowest on all three tests. In other words, groups of students with greater mental ability also tend to achieve, other things being equal, superior results on the course examinations, Introduction to USAF and Administration and Military Management.

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In a previous section of this report a brief survey of the school average scores showed a wide variation in test performance. Various factors affect student performance on examinations. One of the most critical of these factors is the mental caliber of the students concerned. Since mental ability positively affects student accomplishment this factor should be considered in any testing program where one of the purposes for which an examination is utilized is the evaluation of the effectiveness of instruction. It is manifestly unfair to draw conclusions concerning the effectiveness of two instructors on the basis of their student performance on an achievement test if the class of one instructor is brighter mentally than the class of the other instructor. Therefore, some method must be utilized whereby due allowance is made for the mental ability differential existing between the two classes which are to be compared. The method employed here while admittedly not too refined will provide approximate estimates of inter-school accomplishments. At any rate, it is a forward step in the direction of fairer inter-school comparison in that account is taken of the facts of mental ability or scholastic aptitude differences that are known to exist from school to school.

Moreover, it should be clearly understood that achievement examinations should never be employed as the sole instrument to evaluate the instructor's teaching effectiveness. Other supplementary and corroborative evidence must be utilized.

The ROTC RQ-3 examination was used to measure mental ability or scholastic aptitude. This test was administered to the students during their freshmen year. While it would have been better to have used RQ-3 test ratings of the students who remained and took the advanced courses, this could not be done because mental test ratings of the advanced students were not available. Moreover, since we are not dealing with a comparison of one student with another student but between groups of students that is, schools, the relative standings of the various schools in mental ability will probably not change much from the first to the second years. A further assumption needs to be made, however, and that is that the attrition rates are not affected too seriously by the withdrawal of disproportionate numbers of above, average, or below average students when the decision to continue with the advanced courses is made. It is expected that in future reports of this nature mental ratings of students who are taking the advanced courses will be available for use.

Method

Essentially the method that will be employed to evaluate instruction will be the comparison of the two percentile positions achieved by a school, namely, the percentile achieved by the school on the achievement examination will be compared by the percentile attained by the same school on the ROTC RQ-3 test. Percentiles indicate relative positions among a group of schools. Schools should approximately achieve to a degree that is commensurate with the mental caliber of its students. If the mental caliber of students of a school is about average then, other things being equal, they should as a group attain an average mark on the achievement or course examination. Again, if a school places near the top of the group of school, for example, at P90 or the ninetieth percentile on the mental test, then one might expect that school to achieve somewhere near the ninetieth percentile. In other words, the percentile ranking of the school on the RQ-3 test may furnish an approximate indication of expected relative position on an examination given to schools whose students took the same advanced course.

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Evaluating Instructions in Introduction to USAF

Table 52 gives the percentile rankings of the schools on the basis of the RQ-3 test results. A distribution of the school average scores on the mental test was made and eleven percentiles P97, P90, P80, P70, P60, P50, P40, P30, P20, P10, and P1 were calculated. These percentiles for the RQ-3 test serve as expectancy indices, that is, furnish an indication of estimated relative position on course examination.

TABLE 52

Distribution of School Averages and Selected Percentiles on the ROTC RQ-3 Examination

Distribution of Averages		Score Value of Percentiles	
School Average Scores	No.	Average Score	Percentile
143-145	1	144	99%
140-142	3		
137-139	4		
134-136	7	135	90%
131-133	10	131	80%
128-130	17	128	70%
125-127	23	127	60%
		126	50%
		124	40%
122-124	28	123	30%
		122	20%
119-121	19	120	10%
116-118	5		
113-115	2		
110-112	0		
107-109	1	107	1%
Total	112		

The ROTC RQ-3 test was given to 19,660 students in 112 different schools. The left half part of Table 52 shows that the school averages on the RQ-3 test range from 107 to 145. Of the 112 participating schools, 97 of them or 87% attain mean scores between 119 and 133. With such wide variation in student scholastic aptitude one can reasonably expect differential achievement. Moreover, evidence of effective utilization

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of student personnel would be reflected in student achievement that conforms approximately to the mental ability differences among the schools.

Table 53 shows the percentile positions for each school on both the ROTC RQ-3 and Introduction to USAF examination.

TABLE 53

Actual Achievement School Percentile Ratings,
Placement of 112 Schools on the Introduction to USAF Examination

(Left side of table, printed sideways: Achievement Expectancy Placement School Percentile Ratings of 112 Schools on the RQ-3 Test.)

	No. of Schools	Group VC 0% to 20%	Group IVC 21% to 40%	Group IIIC 41% to 60%	Group IIC 61% to 80%	Group IC 81% to 100%
Group IR	22	3	2	6	4	7
81% to 100%		14%	9%	27%	18%	32%
Group IIR	21	4	4	1	4	8
61% to 80%		19%	19%	5%	19%	38%
Group IIIR	22	5	5	5	6	1
41% to 60%		23%	23%	23%	27%	4%
Group IVR	19	3	6	2	1	7
21% to 40%		16%	32%	10%	5%	37%
Group VR	28	8	8	7	4	1
0% to 20%		29%	29%	25%	14%	3%
TOTAL	112	23	25	21	19	24

Along the top of the table are percentile intervals for the course examination and along the left hand side of the table are the percentile intervals for the RQ-3 test. The percentiles have been grouped into fifths so that Group I represents the top fifth, that is, percentiles 81 to 100 and Group V represents the bottom fifth, that is, percentiles 20 and below.

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Groups II, III and IV represent corresponding intermediary fifths. For easy reference and increased clarity successive fifths on the RQ-3 test are labeled Group IR, Group IIR, Group III R, Group IVR and Group VR; the successive fifths on the course examination are labeled Group IC, Group IIC, Group IIIC, Group IVC and Group VC.

Of the 112 schools 22 of them placed in Group IR on the RQ-3 test, 21 placed in Group IIR, 22 in Group IIIR, 19 in Group IVR and 28 in Group VR.

Of the 22 schools whose RQ-3 average score placed them in Group IR, 3 placed in the bottom fifth (Group VC) on the course examination, 2 in Group IVC, 6 in Group IIIC, 4 in Group IIC, and 7 in Group IC. Therefore, of the 22 Group IR schools which may be expected to achieve in Group IC on the course examination only 7 or 32% actually achieved that standing, 4 or 18% actually achieved a Group IIC rating, 6 or 27% actually achieved a Group IIIC rating, 2 or 9% actually achieved a Group IVC rating and 3 or 14% achieved a Group VC rating. One may reasonably conclude that schools whose RQ-3 grouping was IR but who actually achieved in Groups IIIC, IVC and VC should strive for better results next year. Assuming of course that the present utilization of RQ-3 results is a valid one. If we combine the percents for Groups IC and IIC we may say that about 50% of Groups IR approximately achieved expected achievement.

Of the 21 schools whose RQ-3 average score placed them in Group IIR, 38% placed in Group IC, 19% in Group IIC, 5% in Group IIIC, 19% in Group IV C and 19% in Group VC. It may be concluded that schools whose RQ-3 grouping was IIR but who actually achieved in Groups IVC and VC should strive to improve their ranking next year. If we combine the percents for Groups IIIC, IIC and IC we may say that about 62% of Group IIR achieved or surpassed expected achievement. It should be noted that of the Group

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IIR while 19% actually achieved a Group IIC rating, 19% of them also achieved a Group VC rating, that is, the lowest rating.

Of the 22 schools whose RQ-3 average score placed them in Group IIIR 4% placed in Group IC, 27% in Group IIC, 23% in Group IIIC, and 23% in Group VC. It may be concluded that schools whose RQ-3 grouping was III (Group IIIR) but who actually achieved in Group VC should strive to improve their ranking next year. If we combine the percents for Groups IC to IIIC we may say that about &&% of Group IIIR achieved or surpassed expected achievement.

Of the 19 schools whose RQ-3 average score placed them in Group IVR, 37% placed in Group IC, 5% in Group IIC, 10% in Group IIIC, 32% in Group IVC and 16% in Group VC. It may be concluded that schools whose RQ-3 grouping was IVR but who actually achieved in Group VC should strive to improve their ranking. One should make note of the fact that 37% of the Group IVR achieved in Group IC. In other words, the performance of some of these schools in Group IVR is as good or better than that for some of the schools in Group IR and Group IIR. If we combine the percents for Group IC to IVC, we may say that about 84% of Group IVR achieve or surpass expected achievement.

Of the 28 schools whose RQ-3 average score placed them in Group VR, 3% placed in Group IC, 14% in Group IIC, 25% in Group IIIC, 29% in Group IV and 29% in Group V. As a group, Group VR is achieving as good as one can expect from students of lower mental caliber.

<u>Summary of Findings</u>

The findings may be listed as follows:

1. The differential between course achievement and expected achievement is greatest among the top caliber schools. Every effort

should be made to utilize student time to produce superior performance commensurate with their superior talents.

2. About 50% of the schools in the top fifth on the RQ-3 test approximately attained expected achievement.
3. About 62% of the schools in the second top fifth in the RQ-3 test reached or surpassed expected achievement.
4. About 77% of the schools in the third fifth on the basis of the RQ-3 test attained or surpassed expected achievement.
5. About 84% of the schools in the lower fourth fifth on the RQ-3 test achieved or surpassed expected achievement.
6. As a group the lowest group in the RQ-3 test achieved as well as may be expected.

In subsequent surveys where both an achievement test and scholastic aptitude test are to be utilized as part of the program of evaluation of effectiveness of instruction, it is contemplated that another form of the RQ-3 test be administered to advanced students, for these are the students who will eventually graduate as commissioned officers. Mental testing of ROTC junior students would furnish an assessment of the mental caliber of potential officer personnel and will at the same time afford mental ratings the recency of which would make for a more adequate comparison with concurrent achievement examinations.

The analysis of the effectiveness of instruction in Introduction to USAF has served as an example in the evaluation of student achievement. In future course examination surveys when appropriate mental ability tests also will be given to the students, evaluation of achievement in the other courses will be reported in more detail.

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COMPARISON OF RESULTS OF AIR ROTC COURSE EXAMINATIONS 1948-1949 and ROTC QUALIFYING EXAMINATION RQ-3-1949

Percentile Ranks of All Air ROTC Schools on Course Examinations and ROTC RQ-3

In order to make adequate comparisons as to the achievement among the schools on different examinations, it is necessary to transmute raw test scores into a common system of grading. A simple method that may be utilized with this group of eight tests and student populations is the percentile ranking procedure. The distribution of the school averages for each examination was divided into percentiles.

Percentile ranks based on less than thirt schools are to be regarded as best estimated values, however, they were calculated in order to present a complete picture of the rankings of all schools on all course examinations.

Table 54 is a summary table; the table presents the percentile ranks on the course examinations and the RQ-3 test for all schools in the program.

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TABLE 54

COMPOSITE RESULTS OF AIR ROTC COURSE EXAMINATIONS 1948-1949 AND ROTC QUALIFYING EXAMINATION RQ-3-1949

	Intro. to USAF	Admin.& Mil Manage.	A/C Maint.	Armament	Comms.	Stat.Cont.	Trans.	Supply	Average of Course Percentile Ranks	*Percentile Ranks on Air ROTC RQ-3 1st Yr Basic Students
No. of Schools	112	55	30	7	19	15	12	18		
	**Percentile Ranks of Each School									
FIRST AIR FORCE										
Boston University	75	40							58	77
Colgate University	45	25							35	88
University of Conn.	92							99	96	77
Cornell University	82				50				66	93
Fordham University	90	80							85	80
Harvard University	50					65			58	80
Mass. Inst. of Tech.	42				20				31	96
Univ. of Massachusetts	65						92		79	80
Univ. of N. Hampshire	70	50	70						64	82
New York University	98	97							98	88
Rutgers University	20	20	1						21	88
Syracuse University	60	88					41		63	88
Trinity College	50								50	82
Williams College	50							47	49	93
Yale University	94	89							92	97

*These RQ-3 percentiles may be compared only with those of Introduction to USAF examination. (See also P. 110).

**It should be noted that the course percentile ranks at schools where two or more courses are taught can be only crudely compared. Percentile ranks for one course are not strictly comparable to the percentile ranks in another course because the set of schools involved in the two courses concerned are rarely if ever identical. The greater the degree of overlapping of schools giving instruction in both courses the more valid will be the inter-course percentile comparisons at any one school. Comparable standard scores will be employed in future reports.

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TABLE 54 (continued)

COMPOSITE RESULTS OF AIR ROTC EXAMINATIONS 1948-49

No. of Schools	Introduction to USAF	Administration	A/C Maintenance	Armament	Communications	Stat. Control	Transportation	Supply	Average of Course Percentile Ranks	*Percentile Rank on Air ROTC AQ-3
	**Percentile Ranks of Each School									
FOURTH AIR FORCE										
Arizona State College	45	7	20						24	15
University of Arizona	50							37	44	70
University of California	50				1			80	44	82
Fresno State College	9								9	30
University of Idaho	95	94			70				86	30
Loyola University *	80								80	30
Montana St. College	80				62				71	45
Montana St. University	82							65	74	70
University of Nevada	7	19	9						12	40
Oregon State College	25				30		7		21	45
University of Oregon	60	45				46			50	45
San Jose St. College	50	35					35		40	45
University of So. Calif.	65		23						44	50
Stanford University	90		27						59	88
Utah St. Agric. College	40	97		99	99				84	9
University of Utah	40	60	50						50	70
St. Coll. of Washington	82				83	65			77	20
University of Washington	45	35	50						43	50

* and ** See page 118

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TABLE 54 (continued)

COMPOSITE RESULTS OF AIR ROTC EXAMINATIONS 1948-49

No. of Schools	Intro. to USAF	Adminis.	A/C Maint.	Armament	Communications	Stat. Control	Trans.	Supply	Average of Percentile Ranks	*Percentile Ranks on Air ROTC RQ-3
	**Percentile Ranks of Each School									
NINTH AIR FORCE										
University of Akron	70	99					35		58	73
University of Cinn.	70	63							67	70
Duquesne University	20	20							20	15
Georgetown Univ.	7			1					4	70
Gettysburg College	92					80			36	77
Howard University	1						44	85	43	8
Johns Hopkins Univ.	85	67			70				74	90
Univ. of Kentucky	98	10	50						53	30
Lehigh University	82				13		1		32	99
Univ. of Maryland	20		65					70	52	70
Ohio University	55					1		90	49	15
Ohio State University	30		82					65	59	30
Penn. State College	35	73	99						69	73
Univ. of Penn.	80	60				88			76	92
Univ. of Pittsburgh	91	57				99			82	60
Virginia Military Inst.	94	77	65						79	40
Virginia Poly. Inst.	30	35			10				25	40
W. Kentucky St. Teachers	30	45							38	9
West Virginia Univ.	60	92	69						74	9

*

** See preceding page

TABLE 54 (continued

COMPOSITE RESULTS OF AIR ROTC EXAMINATIONS 1948-49

No. of Schools	Intro. to USAF	Adm.	A/C Maint.	Armament	Comms.	Stat.Cont.	Trans.	Supply	Average of Percentile Ranks	*Percentile Ranks on Air ROTC AS-3
	**Percentile Ranks of Each School									
TENTH AIR FORCE										
Ball St. Tchs.Coll.	40								40	15
Bradley University	45								45	45
Butler University	99								99	30
Coe College	45								45	45
Col. St. Coll. of A&MA	20		33				20	20	23	20
Univ. of Denver	60	73	20						51	20
Indiana University	75	50						43	56	45
University of Ill.	85	88	65						79	77
Iowa St. Tchrs Coll.	35				55	80			57	60
St. Univ. of Iowa	20	86				65			57	60
Kansas St. College	92	84	80						85	40
University of Kansas	75	57		40					57	60
Michigan Coll. of M&T	20		40						30	60
Michigan St. Coll. A & AS	35	1	70						35	50
University of Mich.	35	86							61	90
University of Minn.	65				55			30	50	82
University of Minn. (Duluth)	5								5	50
University of Missouri	55	80		93					76	30
University of Nebraska	70	94			30				64	45
No. Dakota Agric.Coll.	20	25							23	20

* and ** See page 118

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TABLE 54 (continued)

COMPOSITE RESULTS OF AIR ROTC EXAMINATIONS 1948-49

No. of Schools	Intr. to USAF	Adm.	A/C Maint.	Armament	Comms.	Stat.Cont.	Trans.	Supply	Average of Percentile Ranks	Percentile Rank on Air ROTC AQ-3
	**Percentile Ranks of each School									
TENTH AIR FORCE										
University of N. Dakota	8	35							22	70
University of Notre Dame	70	16			35				40	60
Parks College	91								91	86
Purdue University *	65		27						46	86
St. Louis University	25								25	96
College of St. Thomas	35								35	60
So. Dakota St. College	82						99		91	80
Superior St. Tchrs. Coll.	9								9	9
Washburn Mun. Univ.	35								35	40
Wayne University	20					13			17	50
University of Wichita	96	57						10	54	70
University of Wisconsin	25		65					20	37	70
University of Wyoming	25	25							25	40

* and ** See Page 118

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TABLE 54 (continued)

COMPOSITE RESULTS OF AIR ROTC EXAMINATIONS 1948-49

No. of Schools	Intr. to Gen.	Engrs.	A/C Maint.	Armament	Comms.	Stat. Cont.	Trans.	Supply	Average of Percentile Ranks	*Percentile Rank on Air ROTC [illegible]-3
	Percentile Ranks of Each School									
[illegible] AIR FORCE										
A & M College of Texas	20	3	9						11	30
Univ. of Arkansas	80					65	50		65	10
Baylor University	7								7	15
La. St. Univ.	70	77	27						58	20
New Mexico Coll. of A & MA	30							1	16	50
Oklahoma A & M	60	50	23						44	20
Univ. of Oklahoma	5[illegible]		40			40			45	50
Southern Meth. Univ.	10								10	88
So. Western La. Inst.	26								2[illegible]	7
Univ. of Texas	25	40			25				30	40
Texas Tech. College	[illegible]0	70		19					56	10
Tulane University	40	25			50				38	50

* and ** See Page 118

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TABLE 54 (continued)

COMPOSITE RESULTS OF AIR ROTC EXAMINATIONS 1948-49

No. of Schools	Intro. to USAF	Admn.	A/C Maint.	Armament	Comms.	Stat. Cont.	Trans.	Supply	Average of Percentile Ranks	*Percentile Rank on Air ROTC AQ-3
	**Percentile Ranks of Each School									
FOURTEENTH AIR FORCE										
University of Alabama	7	20							14	60
Alabama Poly. Inst.	40		80			20			47	10
The Citadel	75							75	75	20
Clemson Agric. Coll.	50		50				47		49	20
S. Carolina Tchrs. Coll.	10								10	8
Univ. of Florida	82	70						90	81	30
Ga. Inst. of Tech.	40	67	84						64	80
Univ. of Georgia	30	55				33			33	10
Univ. of Miami	20								20	20
Miss. St. Coll.	40	30		68					46	40
Univ. of Miss.	25	7						7	13	10
N. Carolina St. Coll. of A & M	91		92		60				81	30
Univ. of N. Carolina	55					65			60	30
Univ. of Tenn.	93			77	90				87	77
Tuskegee Inst.	60						85		73	1

* and ** See Page 118

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An examination of the course percentile ratings attained at each school gives one type of indication of the level of instruction reached by instructor-personnel at that school. Instructor personnel at all schools should carefully examine these rankings. A common practice, though not too accurate a recommendation, followed by personnel in a supervisory capacity is to assume that schools in the lowest ten, twenty, or thirty per cent of the schools taking an achievement examination are doing very poorly. This may, or may not, be true. If these students from a school in the lowest percentiles are as a group much below average in mental ability, or scholastic aptitude, their poor achievement will probably be low as compared to better able students, but the former students may still be achieving up to their mental input. On the other hand, when a school with very superior students is achieving an average score, these students as a group are not functioning up to their maximum capacity. For the latter group of students, changes in methods of instruction need to be made and more often than not better ways of motivation need to be employed.

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In order to more adequately consider achievement in relation to intelligence, Table 54 gives both the percentile ranks on the course examinations and the qualifying examination, ROTC RQ-3. The column headed "Percentile Ranks on Air ROTC RQ-3, 1st Year Basic Students" gives percentile rankings in mental alertness. For each school and on each examination taken at this school, the percentile rankings on the course examinations may be compared. The comparison of the course examination percentiles and the RQ-3 percentiles given in Table 54 can not afford too sound a base upon which to draw definite conclusion because the ROTC RQ-3 test was given to freshmen students, whereas the course examinations were given to junior and senior students. However, hints and clues as to the effectiveness of instruction may be learned from comparisons of course examination percentiles and mental ability percentiles for schools where the discrepancy between these two percentile rankings are greatest. The most adequate comparison between achievement percentiles (course examination) and ability (ROTC RQ-3) percentiles can be for the course examination, Introduction to USAF, because the same set of schools took the latter and the ROTC RQ-3. For similar comparisons between other course examinations results, e.g., Armament and ROTC RQ-3 results, re-ranking on the RQ-3 test results for schools taking the armaments examination must be made. This type of analysis has not been made and, while important, has been deferred to next year's report when more adequate RQ-3 test results will be made available. See Appendix 1 for the evaluation of instruction in the other course examinations.

Of the 112 schools which took the Introduction to USAF, 51 schools received achievement percentiles higher than their mental ability per-

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centiles, 9 schools had identical percentile rankings in achievement and mental ability, while 52 schools attained achievement percentiles less than their mental ability percentiles. Of these 52 schools, 17, or about thirty-three per cent of them, had achievement percentiles that were 37 percentile points or more below their ability percentiles. Therefore, the achievement of schools showing achievement percentiles which were 37 or more percentile points less than their ability percentiles may need to be examined more closely, with a view toward possible modifications in the instructional programs.

A distribution of the achievement and ability percentile differences for the 52 schools where the achievement percentiles were less than the ability percentiles is given in Table 55.

TABLE 55
Achievement Deficiencies in Terms of Percentile Points
at 52 Air ROTC Schools

Introduction to USAF Examination

Intervals of Achievement Ability Percentile Differences	No. of Schools
- 73 to -78	1
- 67 to -72	2
- 61 to -66	2
- 55 to -60	1
- 49 to -54	3
- 43 to -48	4
- 37 to -42	4
- 31 to -36	2
- 25 to -30	8
- 19 to -24	5
- 13 to -18	5
- 7 to -12	8
- 1 to - 6	7
Total	52

The median deficiency was about -25 percentile points.

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On the other hand, of the 112 schools which took the examination, Introduction to USAF, 51 schools received achievement percentiles higher than their mental ability. A distribution of these achievement and ability percentile differences for the 51 schools where the schools achievement percentiles were greater than the ability percentiles is given in Table 56.

TABLE 56
Achievement Proficiency in Terms of Percentile Points at 51 Air ROTC Schools

Introduction to USAF Examination

Intervals of Achievement Ability Percentile Differences	No. of Schools
+ 67 to + 72	4
+ 61 to + 66	3
55 to + 60	2
+ 49 to + 54	6
+ 43 to + 48	0
+ 37 to + 42	3
+ 31 to + 36	3
+ 25 to + 30	10
+ 19 to + 24	2
+ 13 to + 18	7
+ 7 to + 12	5
+ 1 to + 6	6
Total	51

Of these 51 schools, 17, or about thirty-three per cent of them had percentiles that were about 38 percentile points or more above their ability percentiles. The selection of the top third of the group, while arbitrary, may be considered as a standard of achievement in instructional effectivness, and schools which have attained about 38 percentile points or more above their ability percentile standing are probably achieving at a high level of merit. The median is about + 28 percentile points.

CHAPTER VII

SUMMARY AND CONCLUSION

Role of Air-Force-Wide Examinations

Air-force-wide course examinations may be utilized to answer a prime question, "Are Air Force ROTC schools achieving the objectives that they are supposed to reach?" These examinations can be used to guide and motivate learning, to measure how much, how well, and how rapidly each student has progressed, to serve as a basis for the removal of individual and class difficulties, to help evaluate the achievement of each student in terms of his ability and effort and to give the instructor one reading as to how well his instruction is received by his students. Moreover, when supplemented by other subjective measures, the results of objective course examinations provide a factual basis for recommendations for changes in personnel, procedures, and policies.

Air-force-wide course examinations are deemed necessary and therefore will continue to be administered as part of the instructional and evaluational phases of the educational program. Since many and diverse types of schools are involved in the Air Force ROTC program, a common standard yardstick for the evaluation of instruction is vital for valid appraisal and comparison of schools concerned. Furthermore, cooperation among teachers planning to cover requirements previous to the course examination, the discussion of aims and the basis for selecting material, the acceptance of a distinctive core of minimum essentials for each unit of study, and the equalization of standards among different teachers, are among the definite benefits that may be derived from a good evaluation program. However, if uniform examinations are to be utilized effectively, there must be a realization both by the supervising officer and the instructor that these standard course examinations do. measure at least the minimum essentials

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for a course of study, and that an instructor's most valuable service to the program lies in the individual contribution that each instructor gives to his classes in addition to covering the content agreed upon.

In the future, the course examinations will be more systematically constructed with the planned cooperation of the instructors in the field. The examinations will henceforth be constructed so as to be as diagnostic as is feasible. One approach that will be employed to make the course examinations more diagnostic is to group test items in topical sub-groups.

Should course examinations be administered annually, or twice a year? The advantages and disadvantages for course examinations twice a year are still being weighed and no decision has yet been reached.

It is recommended that these examinations be given in lieu of the end-of-term examination, and that the results of this examination contribute to the student's final term grade.

Where schools have not already done so, course examination marks should be entered on each student's record card or file.

Course Achievement of Air Force ROTC Schools

The Air Force ROTC course examinations were administered to 8092 students in 112 colleges and universities throughout the United States. The examinations covered the areas in Administration and Military Management, Aircraft Maintenance Engineering, Armament, Communications, Introduction to USAF, Statistical Control, Supply and Transportation. The latter examinations are achievement tests which cover the important facts, knowledges and understandings in each of the eight Air Force ROTC courses.

The number of schools taking each course examination varied; 112 took the Introduction to USAF examination, while only seven took the Armament examination.

The results of each of the eight examinations reveal a wide range of student achievement.

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The mean or average scores of the eight tests ranged from 55 (Aircraft Maintenance) to 48 (Transportation), and therefore may indicate unequal test difficulty. The question of inter-test difficulty can not be answered unless the mean mental abilities of the various examination groups are known.

The variability in the achievement of the various schools in each examination was wide. More often than not, schools with the lowest means achieved roughly on the average only half as much as the schools which returned the highest examination averages. In Armament, the school with the lowest average achieved roughly about forty per cent as much as the schools with the highest averages. In Statistical Control and Supply, schools with the lowest means achieved about 66 per cent as much as the schools with the highest averages. These inter-school accomplishment quotients are crude overall evaluations.

As an aid in interpreting the school test results, the distribution of school average scores for each examination has been divided into percentiles. Percentiles are points in a distribution of schools below which lie a given percentage of the total number of schools. Schools attaining averages in the bottom 30 per cent of the schools taking a particular course examination may find it highly desirable to initiate changes in methods of instruction, to heighten student interest, and to better utilize curricular materials. However, in evaluating the achievement of the latter group of schools, it is necessary to take into consideration the mental ability of the students concerned.

<u>Consistency of Achievement on Course Examinations Among Air Force ROTC Schools</u>

To what degree do Air Force ROTC schools maintain their rank of merit on 1947-1948 and 1948-1949 course examinations? The degree of correspondence or correlation between these two sets of school rankings can be roughly described as high, marked or substantial, low or negligible. The course examinations

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where high or substantial positive correlations were found were those for Armament, Introduction to USAF, and Administration and Military Management. The three course examinations where the correspondence between the two annual rankings were lowest were Aircraft Maintenance, Statistical Control, and Transportation. In the latter instances, the changes in status may be due to several factors as changes in instructor personnel, student ability and motivation, course content and the like.

It should be noted that for some examinations, the number of schools was small, and hence the results are merely suggestive. Can the schools be judged by the average scores on course examinations achieved by students? Considered for a series of examinations, there seems to be a level maintained by different schools. When the instructional objectives are the same, and the abilities of the students are approximately the same, this teaching level may be considered indicative of the school.

Item Analysis of Air Force ROTC Course Examinations

Each of the eight course examinations contained eighty items. Each item was analyzed for two important aspects, validity and difficulty. A valid test of the type employed in this annual survey should contain items whose validity coefficients are close to .25 or better. The three course examinations having the highest per cent of items meeting the standard of .25 or better are Introduction to USAF, Armament, and Administration and Military Management. Of the eight examinations, all except that on Statistical Control met acceptable standards from the point of view of item validity. The item validities of the 1948-1949 examinations showed improvement of those for the 1947-1948 course examinations. The examination in Introduction to USAF ranked first in both years. As a group, the 1948-1949 examinations showed a high order of overall item validity.

Each test item was analyzed for its difficulty, that is, the number or per cent of the students who were able to pass the item. All eight examinations showed a deficiency of item-difficulty per cents in the intervals from 30 per cent and below. The bulk of the item-difficulty per cents were in the interval 61% to 90%. There were too many easy items (100% to 90% difficulty) on all examinations except, perhaps, that in Transportation. In all eight examinations the average per cent difficulty for 1948-1949 was equal or higher than those for 1947-1948. The average of the eight average per cent item-difficulties for 1947-1948 was 63.6%, while the average of the eight average per cent item-difficulties for 1948-1949 was 70.2%. It is felt that for this type of annual examination, and in view of the purposes to which it is anticipated that it will be put, the average difficulty of a course examination should not go beyond 65 to 70 per cent.

The analysis of items as to validity coefficients is an important one to make for the instructor as an examiner. However, an equally significant analysis of the items from the point of view of the instructor as a teacher is the one that reveals the specific items which were passed or failed by the students. Attention might be drawn to those items where the pass-per cents are 50% or less. Close scrutiny should be given this group of items as they may reveal student weak spots and indicate to the instructor the curricular sub-topics where instruction is needed or where superior instruction should be offered in subsequent lesson periods. Moreover, items which were failed by many students and which, in the opinion of the instructors, represent fundamental facts or concepts which should be understood by the average student should be taught more effectively next year.

Results of the ROTC Qualifying Examination RQ-3 -- 1949

The RQ-3 examination, a survey type test of learning ability, was administered to all 19,660 First Year Basic AF ROTC students in 112 schools during the academic year 1948-1949. There are several benefits that accrue as a result of the administration of the RQ-3:

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1. It affords a scientific means of checking on the mental ability level of potential commissioned officers who select, drop out, or advance through the Air Force ROTC program. A check inventory of this type is basic to a properly administered personnel selection, classification, and utilization program.
2. The RQ-3 test can be utilized to evaluate student accomplishment in relation to their mental ability.
3. The test supplies objective psychological data which the instructor should reflect by appropriate modifications in teaching techniques, motivation and curricular materials.
4. The test results can be used to help set up equitable standards of achievement for large groups of schools with wide variations in learning ability.
5. The test results will supply essential data for future survey, research, and evaluation projects.

Because of the above advantages, mental ability testing programs should be continued and amplified consistent with practicality and the needs of the service. However, because of the very nature of a short group test of the RQ-3 type, the reliability of an individual score will not be as reliable as the mean standard scores of a school. In view of this fact, it may be justified if a longer and more reliable test be substituted. Because of certain difficulties attendant upon the administration of a longer mental ability test, it might be desirable to use an equivalent RQ-3 test at the freshman year and the longer and more reliable test in the advanced years.

The results on the RQ-3 test showed wide variations among the 112 schools. The mean standard school scores ranged from 107 to 145. With such wide variation in learning ability we can reasonably expect a wide range in achievement; and that in evaluating student course achievement one must seriously consider this differential in learning ability. No forms for the ROTC RQ-3 test are currently available and for the present the Air Force-wide median of 126 may be taken to represent the national standard. Of the six Air Forces, the First Air Force, with an average score of 135, achieved top rank.

Evaluation of the Effectiveness of Instruction

A brief survey of the school average course scores showed a wide variation in test performance. Since mental ability of the students concerned positively affects student accomplishment, this factor should be considered in any appraisal of instruction. A method which combined the results on the ROTC RQ-3 test and the course examination was utilized whereby due allowance was made for mental ability differential existing between schools. The method employed was to compare the two percentile positions achieved by a school, namely, the percentile achieved by the school on the course or achievement examination and the percentile attained by the same school on the RQ-3 test. Percentiles indicate relative positions among a group of schools.

Schools should achieve approximately to a degree that is commensurate with the mental caliber of its students. If the mental caliber of the students of a school is about average, then, other things being equal, they should as a group attain an average score on the course or achievement examination. The fullest exploitation of this evaluation method could not be accomplished because the RQ-3 test was given to students during their freshman year, therefore, it was tentatively assumed that the relative standing of the schools in the freshman year in mental ability was about the same as the relative standing of the same schools in the junior year. In subsequent surveys, a learning ability test will be administered to advanced students.

Therefore, in view of the necessary limiting assumptions which had to be made, one course examination, that of Introduction to USAF, was selected for analysis and served as an example in the evaluation of school achievement.

Bearing the specified limitation in mind, the analysis of the effectiveness of instruction in Introduction to USAF shows that:

1. The differential between course achievement and expected achievement is greatest among the top caliber schools. Every effort should be made to utilize student time to produce superior performance commensurate with their superior talents. About 50% of the schools in the top fifth on the RQ-3 test attained expected achievement.
2. About 62% of the schools in the second fifth, about 77% of the schools in the third fifth, and about 84% of the schools in the fourth fifth, attained or surpassed expected achievement.

3. As a group, the lowest group on the RQ-3 test achieved as well as may be expected.

The comparison of the course examination percentiles, and the ROTC RQ-3 percentiles cannot afford too sound a base upon which to draw definite conclusions, because the RQ-3 test was given to freshman students, whereas the course examinations were taken by junior and senior students. Yet, suggestive clues as to the effectiveness of instruction may be gleaned from comparisons of course examination percentiles and mental ability percentiles for schools where the discrepancy between these two percentiles is greatest.

The most adequate comparison of achievement and ability percentiles can be made for 112 schools which took the course in Introduction to USAF Seventeen of these schools had achievement percentiles which were 37 percentile points or more below their ability percentiles and therefore they may need to critically examine their instructional programs. For nine schools the achievement and mental ability percentiles were identical. On the other hand, seventeen schools attained achievement percentiles that were about 38 percentile points or more above their ability percentiles. These schools are maintaining superior performance. Although the method employed will provide only approximate estimates of inter-school accomplishments, its use may be considered a forward step in the direction of fairer inter-school comparison in that allowance is made for the mental ability differences that are known to exist from school to school. However, it should be remembered that achievement examinations should never be employed as the sole means to evaluate the instructor's teaching effectiveness. Other supplementary and corroborative evidence, even though subjective, should be utilized.

APPENDIX 1

EVALUATING INSTRUCTIONS IN SEVEN AIR ROTC COURSES

In future course achievement surveys when both mental ability tests and course examinations will be given to all students, evaluation of achievement in the various courses will be more exact and, hence, will give a better picture of the overall student attainment at each school. The evaluative statements as to the effectiveness of instruction in the following seven courses apply only to sub-groups of schools since more definitive data for evaluating instruction at any one school are not available at this time. The data have been presented mostly for exploratory purposes. The latter purpose will be realized if the instructors come to understand and appreciate the concept of evaluating achievement in relation to differential levels of student ability.

Evaluating Instructions in Administration and Military Management

In view of the fact that the number of participating schools which took the Administration and Military Management examination were too few to permit as intensive an analysis of results as that for the course, Introduction to USAF, a more abbreviated method of evaluation will be employed. Table 1 presents the distribution of schools on the basis of the results on the RQ-3 test and the course examination.

TABLE 1

Achievement Expectancy Placement of 55 Schools In the Upper and Lower 50% of Scores on the RQ-3 Test

		No.; Percent of Schools in Lower Half	No.; Percent of Schools in Upper Half	Total Schools
Actual Achievement Placement of 55 Schools on the Admin. & Mili. Management Examination	No.; Percent of Schools in Upper Half	12-43%	16-59%	28
	No.; Percent of Schools in Lower Half	16-57%	11-41%	27
TOTAL		28	27	55

The 55 schools were divided into two large groups, the upper half which contained schools that placed in the top half of the distribution of scores on the RQ-3 test, and the lower half group which contained schools that attained scores in the lower half of the distribution of scores on the RQ-3 test. Other things being equal, schools in the top half on a scholastic aptitute test should more often than not achieve in the top half of scores on a course examination. Of the 27 schools which placed in the top half on the RQ-3 test, 16 or 59% of them attained expected proficiency, that is, 59% also placed in the top half on the course examination. However, 11 or 41% did not attain expected proficiency, that is, 41% of the schools with abler

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students placed in the lower half of the distribution of scores on the course examination.

On the other hand, of the 28 schools which placed in the lower half of the distribution of scores on the RQ-3 test, 12 or 43% surpassed their expected attainment, that is, achieved scores in the upper half of the distribution of scores on the course examination. However, 16 or 57% reached their expected achievement, that is, 57% of the schools in the lower half of the distribution of scores on the RQ-3 test also achieved in the lower half on the course examination.

Evaluating Instruction in Aircraft Maintenance Engineering

Table 2 presents the distribution of schools on the basis of the results on the RQ-3 test and the course examination.

TABLE 2

Achievement Expectancy Placement of 30 Schools In the Upper and Lower 50% of Scores on the RQ-3 Test

		No.; Percent of Schools in Lower Half	No.; Percent of Schools in Upper Half	Total Schools
Actual Achievement Placement of 30 Schools on the Aircraft Maint. Engineering Examination	No.; Percent of Schools in Upper Half	7 - 47%	8 - 53%	15
	No.; Percent of Schools in Lower Half	8 - 53%	7 - 47%	15
TOTAL		15	15	30

The 30 schools were divided into two groups -- the upper half which contained schools that placed in the top half of the distribution of scores on the RQ-3 test, and the lower half group which contained schools that attained scores on the lower half of the distribution of scores on the RQ-3 test. Other things being equal, schools in the top half on a scholastic aptitude test should more often than not achieve in actual performance in the top half of a course examination. Of the 15 schools which placed in the top half of the RQ-3 test, 8 or 53% also placed in the top half on the course examination. However, 7 or 47% did not attain expected proficiency, that is, 47% of the schools with abler students placed in the lower half of the distribution of scores on the course examination.

On the other hand, of the 15 schools which placed in the lower half of the distribution of scores on the RQ-3 test, 7 or 47% surpassed their expected attainment, that is, achieved scores in the upper half of the distribution of scores on the course examination. However, 8 or 53% reached their expected achievement, that is, 53% of the schools in the lower half of the distribution of scores on the RQ-3 test also achieved in the lower half on the course examination.

Evaluating Instruction in Communications

Because the number of schools which participated in the Communications examination program were few, less refined analysis of the test results was possible. The evaluation procedure that will be employed involves the single computation of the crude percent of schools achieving the level of expected achievement. Schools which place in the top half of the range of school mean scores on the RQ-3 test should more often than not also achieve in the top half on the course examinations.

In all, 19 schools took the Communications examination. Of the top 10, that is, top half of this group of schools on the RQ-3 examination, 4 or 40% attained expected proficiency, that is, 40% also placed in the top half on the course examination; 60% of them did not. Of the lowest 9, that is, the lower half of the schools on the RQ-3 test, 3 or 33% also placed in the lower half on the course examination; the other 6 or 6% achieved in the top half on the course examination.

Evaluating Instruction in Supply

The evaluation procedure that will be employed involves the simple computation of the crude percent of schools achieving the level of expected achievement. Schools which place in the top half of the range of school mean scores on the RQ-3 test should more often than not also achieve toward the top half on the course examination.

In all, 18 schools took the Supply examination. Of the top 9, that is, the top half of this group of schools on the RQ-3 examination, 4 or 44% attained expected proficiency, that is, 44% also placed in the top half on the course examination; 54% of them did not. Of the lowest 9, 3 or 33% also placed in the lower half of the course examination; the other 6 or 67% achieved in the top half on the course examination.

Evaluating Instruction in Statistical Control, Transportation and Armament

The evaluation procedure that will be employed for these three examinations involves the simple computation of the crude percent of schools achieving the levels of expected achievement. Schools which place in the top half of the range of school mean scores on the RQ-3 test should more often than not also achieve toward the top half of the mean score on the course examination.

In all, 15 schools took the Statistical Control examination. Of the top 8, that is, the top half of this group of schools on the RQ-3 examination, 6 or 67% of these schools attained expected proficiency, that is 67% also placed in the top half on the course examination in Statistical Control.

The number of schools which took the Transportation examination was 12. Of the top 6, that is, the upper half of the group of schools on the RQ-3 examination, 3 or 50% also placed in the top half of the course examination mean scores on Transportation.

Seven schools took the Armament examination. Of the top 3 on the RQ-3 test, 1 or 33% placed in the top half of mean scores on the course examination, of the bottom 4 schools on the RQ-3 test, 2 or 50% surpassed their expected achievement and placed in the top half of schools which took the Armament examination.

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AIR FORCE ROTC

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CONTINENTAL AIR COMMAND

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Foreword

HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK
25 April 1949

ConAC Manual 50-2 is published for the information and guidance of all concerned. It will be used in conjunction with the current program of instruction pertaining to Air Force ROTC Training.

BY COMMAND OF LIEUTENANT GENERAL WHITEHEAD:

H. M. TURNER
Major General, United States Air Force
Vice Commander

OFFICIAL:

HEADQUARTERS OFFICIAL CONTINENTAL AIR COMMAND

NEAL J. O'BRIEN
Colonel, United States Air Force
Adjutant General

THIS MANUAL SUPERSEDES ConAC Manual 50-200-2 Vol. II, Parts 8, 10, 11 and 14.

Preface

THIS textbook has been prepared specifically for the college or university student who is participating in the Air Force ROTC program. It is one volume of a series designed to qualify him as an officer specialist in the United States Air Force.

The text is planned to indoctrinate the officer candidate in the fundamental principles of Aerodynamics and Propulsion, Weather and Navigation and Applied Air Power, rather than to present a detailed treatise of each of these complex fields.

In order to achieve maximum efficiency and effectiveness in the performance of his duties, the Air Force officer must be constantly aware of new developments in his specialty and its allied fields. A receptive mind, nurtured by supplementary research and reading, can be a vital force in the personal and professional development of the officer specialist throughout his career.

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PART 2—METEOROLOGY AND NAVIGATION

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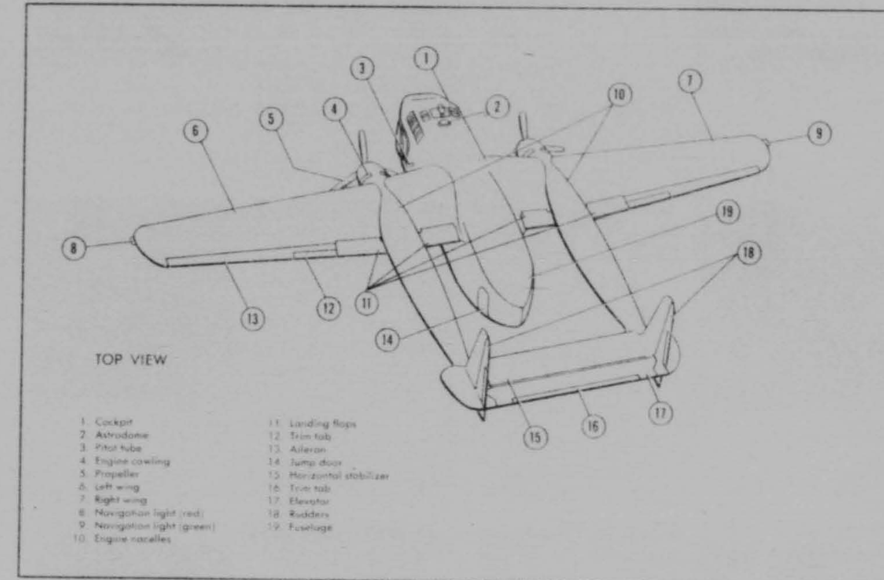
CHAPTER 1 - AERONAUTICAL TERMS AND THE AIRCRAFT



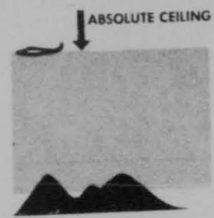
SECTION I - DEFINITION OF AERONAUTICAL TERMS

1. INTRODUCTION

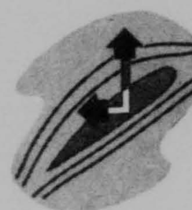
Aerodynamics is the science that deals with the aircraft and its operation. The rapid development of the Air Age has produced a vast body of knowledge related to this science, in which many fields of specialization are being perfected and explored by highly-trained experts. It includes the engineering, construction, operation, and instrumentation of all aircraft; the methods and mathematics of navigation through the air (aero nautics); and that most important of all limiting conditions,—the weather. A detailed investigation of these technical matters is certainly not the purpose here. However, an intelligent understanding of the basic principles of this vital subject must be possessed by every United States Air Force officer. It is necessary, therefore, to make a general survey of the fundamental principles, the progress and the recent developments in the science of aerodynamics.

2. GLOSSARY OF AERONAUTICAL TERMS

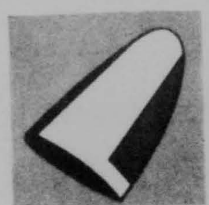
The student will constantly meet new terms connected with aircraft and aeronautics which will need clarification. The following glossary lists some of the more common terms likely to be encountered in elementary work in aviation:



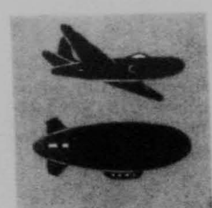
ABSOLUTE CEILING — The height above which a specific airplane cannot climb.



AERONAUTICS — The science and art of flight.

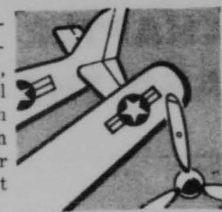


AILERON—The hinged part of the wing, usually on the trailing edge. It controls the motion of an airplane about the longitudinal axis. In other words, it controls roll.

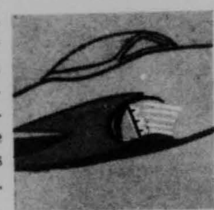


AIRCRAFT — Any weight-carrying device designed to be supported by the air, either by buoyancy or by dynamic action.

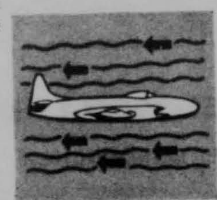
AIRFOIL — Any surface, like a wing, propeller, or rudder, which gets a useful dynamic reaction from the air. (This action results when the air strikes the airfoil at an angle.)



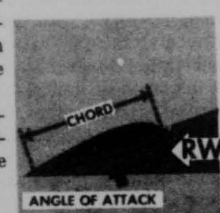
AIR SCOOP — A device for "scooping" air into the aircraft. With reference to jet aircraft it is the carefully-designed air-intake opening which ducts the air to the engine.

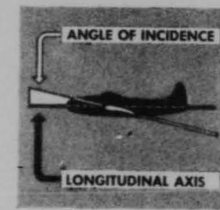


AIR SPEED—The speed of the aircraft relative to the air.

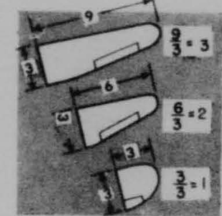


ANGLE OF ATTACK — The acute angle between the chord of an airfoil (wing) and the relative wind. (Note that the longitudinal axis is not always parallel to the relative wind.)

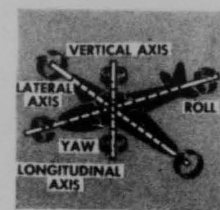




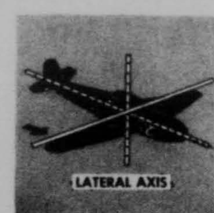
ANGLE OF INCIDENCE — The angle at which the wings are installed on an airplane. Therefore with any given aircraft, this angle does not change. It is the angle between the chord of the airfoil and the longitudinal axis of the aircraft.



ASPECT RATIO — The ratio of the span to the mean chord of an airfoil. Because most wings are not rectilinear, it is generally taken as, "the ratio of the square of the span to the total area of an airfoil."

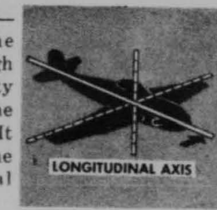


AXES OF AN AIRCRAFT —Three fixed lines of reference, each one through the center of gravity, and perpendicular to the other two.

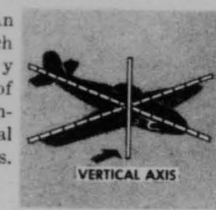


LATERAL AXIS — An imaginary line which runs through the center of gravity and is perpendicular to the longitudinal and vertical axis. Normally from wing tip to wing tip.

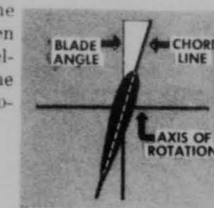
LONGITUDINAL AXIS— An imaginary line which runs through the center of gravity from the nose of the aircraft to the tail. It is perpendicular to the lateral and vertical axes.



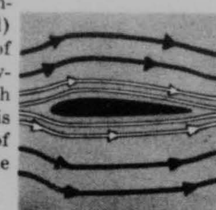
VERTICAL AXIS — An imaginary line which runs vertically through the center of gravity and is perpendicular to the lateral and longitudinal axes.



BLADE ANGLE — The acute angle between the chord of a propeller blade and the plane through which it rotates.



BOUNDARY LAYER — A layer of fluid (considering air as a fluid) close to the surface of a body placed in a moving stream, in which the impact pressure is reduced as a result of the viscosity of the fluid.



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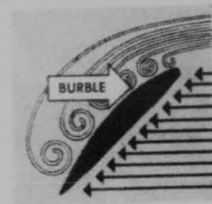
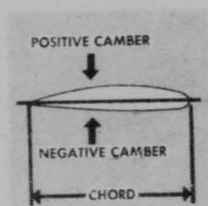
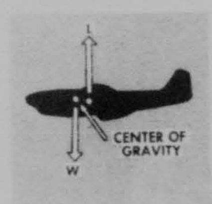


BURBLE — A term designating the breakdown of the streamline flow about a body. This occurs when an airplane reaches a stalling attitude. This is then known as the "Burble Point."

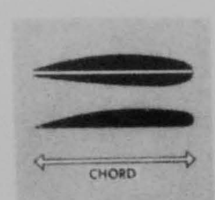
BURBLE POINT — See above.



CAMBER — The curvature of an airfoil above and below the chord line surface.

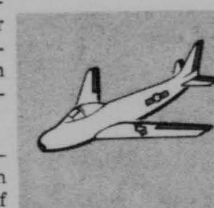


CENTER OF GRAVITY— An imaginary point in a body where the resultant of all forces of gravity is concentrated.

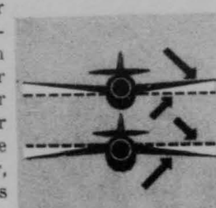


CHORD — An imaginary line connecting the leading and trailing edges of an airfoil.

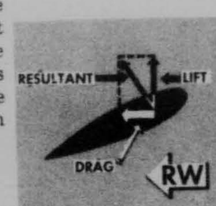
CONTROL COLUMN—A fore and aft lever with a rotatable wheel at its upper end, used for operating the ailerons and elevators of most aircraft. In fighter aircraft this column may be a "stick." Such a stick control in modern fighters is in itself a very advanced column, because in addition to its control function it also becomes the housing for such other mechanisms as the microphone button, gun button, trim tab controls, etc.



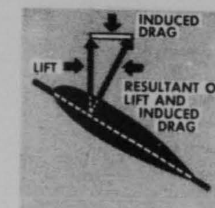
CONTROL SURFACES — Airfoil sections which control movement of the aircraft about its axes. The main control surfaces are ailerons (elevons), elevators, and rudder.



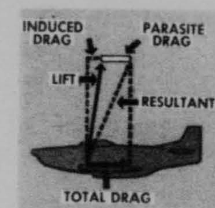
DIHEDRAL—A wing or "horizontal" tail surface design in which the tips are higher, or lower, than the center section of the wing or tail surface. Positive if the tips are higher, Negative if the tips are lower. This improves lateral stability.



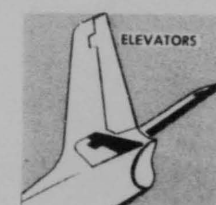
DRAG — The force which tends to resist an airplane's passage through the air. It is parallel, and in the same direction with the relative wind.



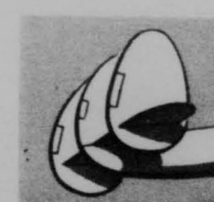
INDUCED DRAG—That drag which is created as a part of the dynamic reaction which creates lift.



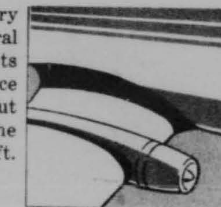
PARASITE DRAG — All drag other than induced drag is turbulence caused by such protuberances as landing gear, radio antenna, rivet heads, etc.



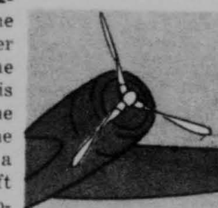
ELEVATOR—A movable airfoil hinged to the horizontal stabilizer. It controls movement about the lateral axis (pitch).



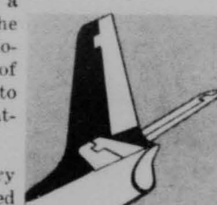
EMPENNAGE—The rear part of an aircraft, usually consisting of a group of stabilizing planes, or fins, to which are attached certain controlling surfaces such as elevators and rudders.



FAIRING—A secondary member of a structural part of an airplane; its purpose is to reduce drag by smoothing out the flow of air over the parts of the aircraft.



FEATHERING A PROPELLER — Causing the blades of the propeller to turn so that the chord of the blade is parallel with the line of flight. This is done when an engine of a multi-engine aircraft fails, to keep the propeller on the "dead" engine from wind-milling in flight.



FIN—A stationary airfoil that is used as a stabilizer, such as the vertical fin that is located just forward of the rudder and to which the rudder is attached.

FLAP— A secondary airfoil that is hinged to or pivoted on a primary airfoil (usually the wing). It is used to increase the effective camber and thus increase the lift. It is also used to increase the angle of attack and thus increase the drag of the primary airfoil, for the purpose of increasing the gliding angle and reducing the landing speed.

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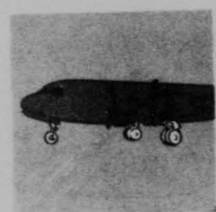
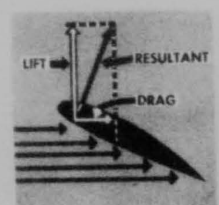
FUSELAGE—The principal structure of the aircraft to which the wings and empennage are normally attached. On large aircraft it usually contains large compartments, bomb bays, etc.



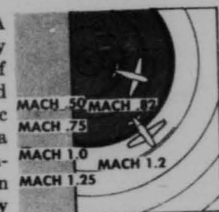
LANDING GEAR — The understructure which supports the weight of an aircraft when in contact with the ground, and which usually contains mechanisms to reduce the shock of landing. (There are many types and uses which will be discussed in a section on landing gear.)

LEADING EDGE — The part of an airfoil which strikes the air first.

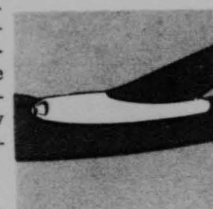


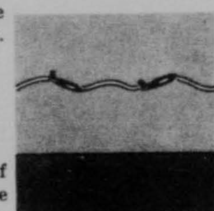
LIFT/DRAG RATIO — The numerical ratio of the lift with respect to the drag. This figure may be used to express the aerodynamic efficiency of an airfoil or of an aircraft as a whole.

MACH. NUMBER — A number determined by dividing the speed of the plane by the speed of sound. A specific type of aircraft has a certain "Mach" number, which it either can not, or can not safely exceed. The speed of sound becomes important in high speed flight because it represents the limit of compressibility of the air. If this limit is exceeded, without specially-designed airfoils, the drag increases so rapidly that normal flow characteristics no longer apply.



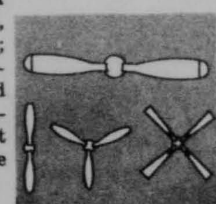
NACELLE — A streamlined enclosure built up around the engine, and its accessories, sometimes including landing gear, distinguished from fuselage because it has no empennage.

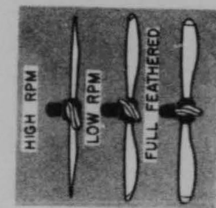




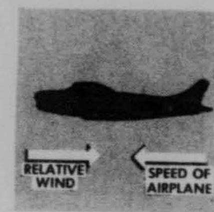
PITCH — Rotation of the airplane about the lateral axis, nose down, nose up.

PROPELLER — Any device for propelling a craft through a fluid, such as air or water; the propeller is an airfoil, and moves forward through the air because as it rotates it creates "lift," the same as any other airfoil.

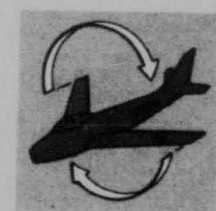




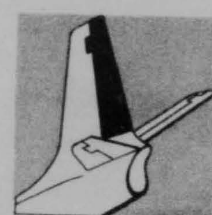
PROPELLER CONTROL — The pitch of the modern propeller may be regulated from low pitch (high rpm) through high pitch (low rpm) to the feathered (stationary) position. Some propellers may be reverse feathered.



RELATIVE WIND — Air moving past the aircraft. It is parallel to but opposite to the direction of the flight path.



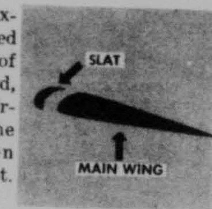
ROLL — Movement about the longitudinal axis created by the ailerons.



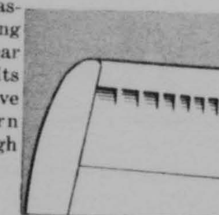
RUDDER — A moveable airfoil hinged to the rear of the vertical fin. It controls yaw.

SKIN FRICTION — The drag which results from the viscosity of the air in passing over a surface. In modern high-speed aircraft this becomes very great, and at supersonic speeds creates so much heat that the cockpit must be refrigerated.

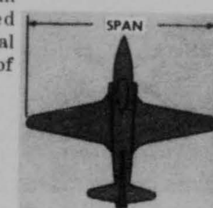
SLAT—A movable auxiliary airfoil, attached to the leading edge of a wing. When closed, it falls within the original contour of the main wing. When opened, it forms a slot. (See "slot" for use.)



SLOT—The ducted passage through a wing parallel to, and near the leading edge. Its purpose is to improve the airflow pattern over the wing at high angles of attack.

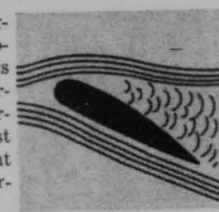


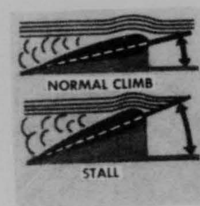
SPAN — The maximum distance, measured parallel to the lateral axis, from tip to tip of an airfoil.



STABILITY—The ability of an airplane with free controls to remain in or return to its normal flying attitude.

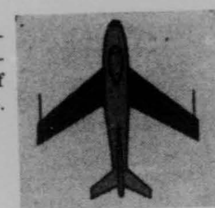
TURBULENCE — Irregular flow of air produced when air flows over an uneven surface, or when two currents of air flow past each other in different directions or at different speeds.

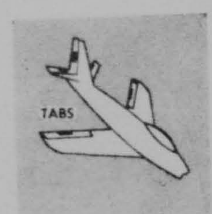




STALL — The point at which the airplane is operating at such an angle of attack that the air burbles and the lift force is insufficient to overcome gravity, and the aircraft no longer is able to maintain normal flight.

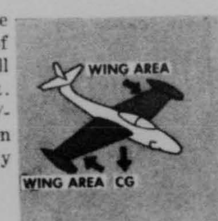
WING — The large airfoil area which develops the major part of the lift of an airplane.





TAB—A small auxiliary surface attached to a control surface for the purpose of reducing the control force necessary for in-flight stability or change of direction and for trimming the aircraft. In high-speed or very large aircraft the force required to actuate control surfaces may be so great that the pilot's control may be directly connected to the tab.

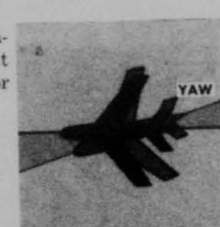
WING LOADING—The weight each sq. ft. of the wing surface will have to support. Weight of airplane/-wing area. In modern aircraft this is usually quite high.



TRAILING EDGE — The rear or following edge of an airfoil such as a wing or propeller blade.

TRIM — To adjust the tabs on the control surfaces so as to secure stability for a desired flight condition with free controls.

YAW — Angular rotation of the plane about the vertical axis, left or right.



SECTION II - NOMENCLATURE OF THE AIRCRAFT

Even though modern aircraft do not look much like the early models which were flown in the air battles of World War I, or like the Curtiss "Condor", or like the NC-4, many of the basic parts bear the same names they had then. Others, because of the evolution of aeronautics, have changed their meaning. "Conventional landing gear" once meant a type with two wheels forward of the center of gravity, and a tail wheel. Today the "conventional" landing gear is the tricycle gear as seen on the C-54, and most other modern types.

On the next few pages there are illustrations of modern aircraft tabbed to show most of the external parts. This list has been prepared to show the parts of a normal aircraft. There are many additions which could be made; but in most cases they would apply infrequently, for example: elevons, fences, tip tanks, etc. The instructor will cover any additional items.

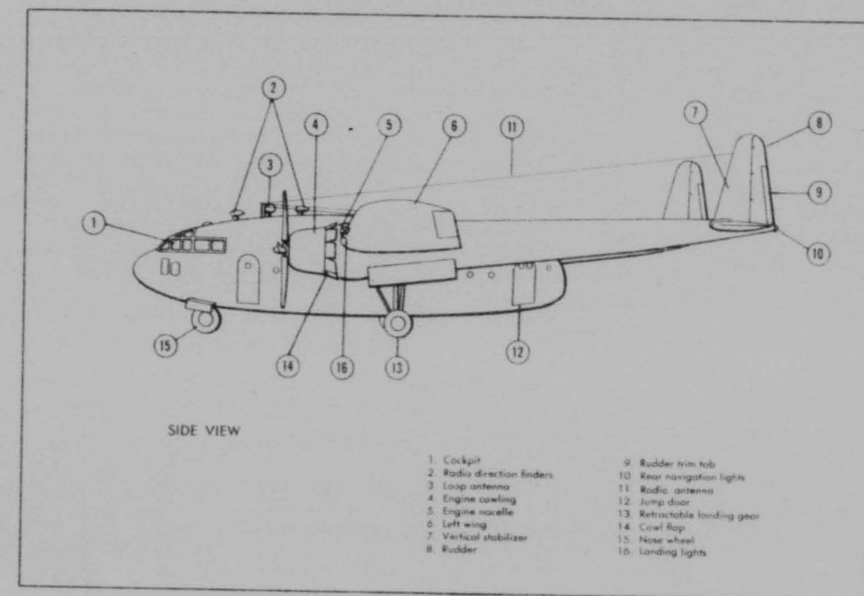


Figure 1-1 Aircraft Nomenclature—Side View

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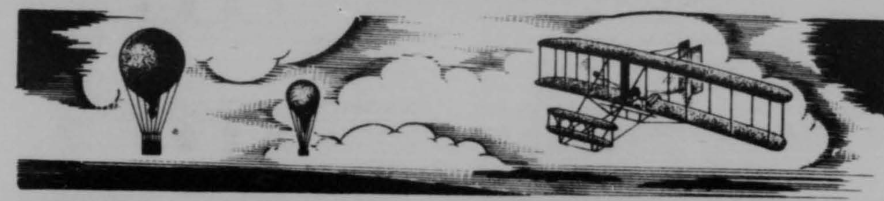
CHAPTER 2 - THEORY OF FLIGHT

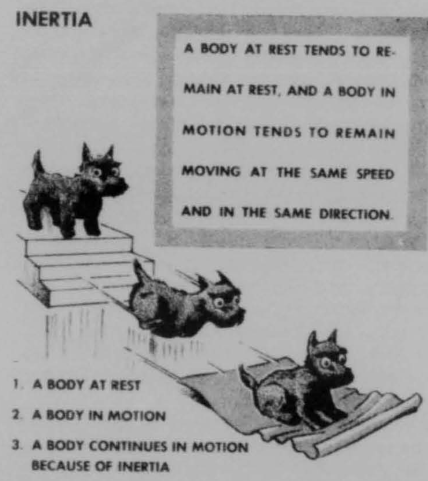


SECTION I - FORCES ON AN AIRCRAFT IN MOTION

Men had known for centuries before the first flight of the Wright brothers at Kitty Hawk in 1903 that heavier-than-air craft would fly. Toys, paper bags filled with hot air, model gliders, even model powered gliders, which had made long, successful flights, had been built. During the nineteenth century experimenters had made countless brief flights in gliders. But, lacking an adequate source of power, none of these men had been able to make a sustained flight.

With the development of the internal-combustion piston engine before the turn of the century, this necessary power plant began to evolve. The Wright brothers, in their Dayton bicycle shop, along with other experimenters all over the world, turned to the internal-combustion engine as a means of providing the necessary power to sustain flight. Already considerable data existed in the field of aeronautics from the earlier experiments of such men as Stringfellow, Pilcher, and others. But the problems involved in the theory of flight are many. Perhaps no other single field of human endeavor has been so complex or so difficult to master. The aeronaut must depend upon the work of master engineers, doctors, electronic experts, and other skilled carftsmen. Yet the basic theory itself is rather simple.

INERTIA



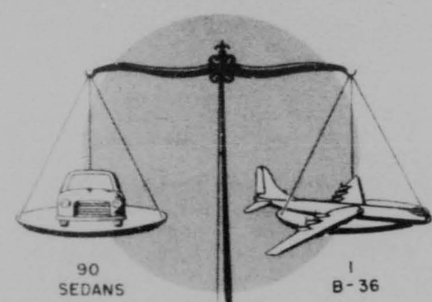
Sir Isaac Newton stated that a body at rest would tend to remain at rest, and that a body in motion would tend to remain in motion. This, of course, applies to aircraft, as well as any other body. Being at rest, an aircraft will remain at rest until the engines are started and enough power is applied to move it. How is this done?

Each engine turns a propeller. Unless we realize that the air is a fluid, which has mass, it seems as though the propellers just whirl in space. But the air is a fluid, and actually, to a fast moving body (the propeller), it is quite dense. For example; when one throws a base-ball, one has no trouble propelling the arm through the air and giving the ball a heave. However, if one stands in water up to one's chin one would have considerable trouble hurling the ball because it is impossible to move the arm fast enough under water. The water has resistance; in effect, it pushes against the arm.

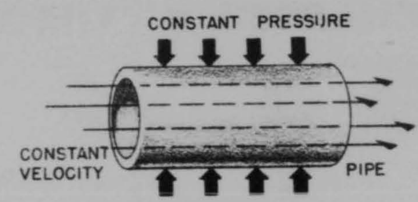
This is exactly what happens in the case of the propeller. Since the propeller is whirling much faster than the arm while throwing the ball, the air, with relation to the high-velocity propeller, has great resistance; and, in effect, it too is pushing the propeller. Again, turning to Sir Isaac Newton, we find that he stated that every action has an equal and opposite reaction. This means, for example, that, when a person walks, he pushes on the floor with a certain action; the floor pushes back on the foot with an equal reaction. One may consider what happens when it does not push back. An example would be a person stepping from the bottom of a rowboat onto the dock. When he pushes on the floor of the boat it does not react equally; and unless he is careful he will fall in the water between the dock and the boat.

When the propeller whirls fast enough so that it is pushing with great force on the air, and the air is reacting with an equal and opposite strong force, the aircraft begins to move ahead. The faster the propeller turns the harder it works and the faster the plane moves down the runway. Then at a certain speed the plane begins to fly. This brings up the next point to be considered.

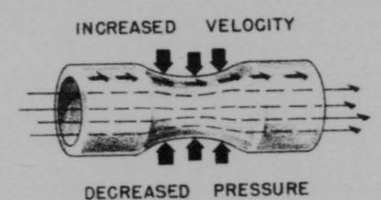
Why does an aircraft fly? How is it that a B-36, weighing as much as ninety automobiles, can rise gently into the air, and fly 10,000 miles at 40,000 feet, while the automobiles are unable to leave the ground? This time the answer does not come from Sir Isaac Newton. Instead we look into the idea presented by Bernoulli, and a few other random principles.



According to Bernoulli, the faster a fluid passes between two points, as in the case of water flowing through a pipe, the less the



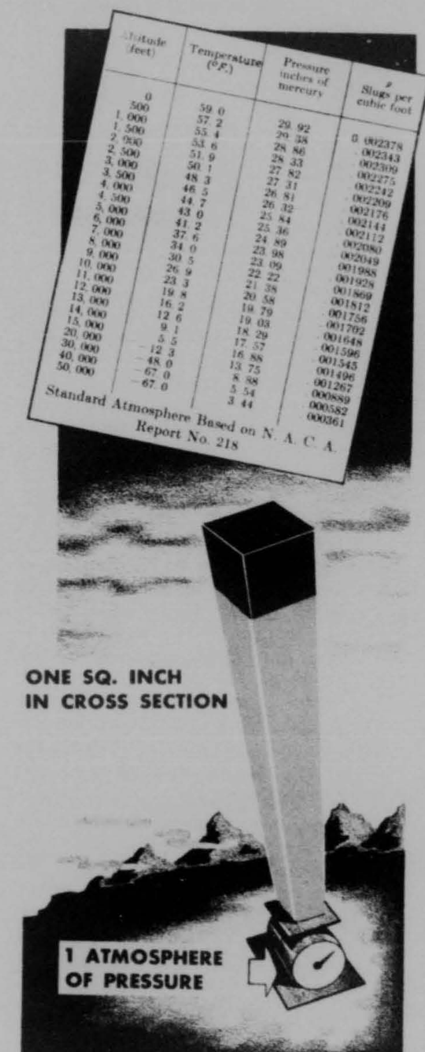
pressure is on those two points. If water is forced at even pressure through a pipe six feet long and two inches in diameter the water will move through the pipe with constant speed and there will be an equal pressure at all points on the walls of the pipe. If a constriction, or throat, is made at a cer-



tain part of this pipe, the diameter at the throat will be smaller. Since the same amount of water leaves the pipe as that which enters it, what happens at this throat? Obviously the same amount must get through the smaller area; so it does the only thing possible. At the throat it speeds up. And then, according to Bernoulli, when it speeds up, the pressure on the wall of the throat decreases,—"when the velocity increases the pressure decreases."

This may be applied to flying. The air at sea level, at standard conditions of temperature and pressure, is constantly exerting a pressure of 14.7 pounds per square inch in all directions. This means that the column of air (which is a fluid mass), above any given square inch of the earth at sea level and extending to the top of the atmosphere will weigh 14.7 pounds. Therefore, this 14.7 pounds is like the pressure on the walls of the pipe in the above example; it is universal and fairly constant.

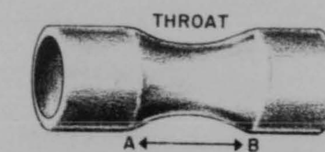
In the pipe the pressure dropped at the throat when the velocity increased. This can be duplicated in the air since air is also



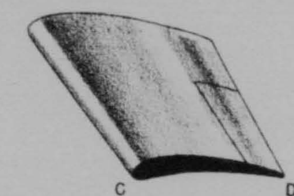
Altitude (feet)	Temperature (°F.)	Pressure inches of mercury	ρ Slugs per cubic foot
0	59.0	29.92	0.002378
500	57.2	29.38	.002343
1,000	55.4	28.86	.002309
1,500	53.6	28.33	.002275
2,000	51.9	27.82	.002242
2,500	50.1	27.31	.002209
3,000	48.3	26.81	.002176
3,500	46.5	26.32	.002144
4,000	44.7	25.84	.002112
4,500	43.0	25.36	.002080
5,000	41.2	24.89	.002049
6,000	37.6	23.98	.001988
7,000	34.0	23.09	.001928
8,000	30.5	22.22	.001869
9,000	26.9	21.38	.001812
10,000	23.3	20.58	.001756
11,000	19.8	19.79	.001702
12,000	16.2	19.03	.001648
13,000	12.6	18.29	.001596
14,000	9.1	17.57	.001545
15,000	5.5	16.88	.001496
20,000	-12.3	13.75	.001267
30,000	-48.0	8.88	.000889
40,000	-67.0	5.54	.000582
50,000	-67.0	3.44	.000361

Standard Atmosphere Based on N. A. C. A. Report No. 218

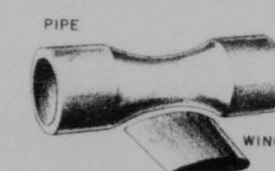
fluid. A diagram of the throat of the pipe would look like this:



The part which we are interested in, is the part from "A" to "B". We know that the part of the aircraft which creates the lift is the wing. If we were to slice the wing of an aircraft in cross section, we would see that it looks like this:



When we draw a line from the leading edge of the wing "C" to the trailing edge of the wing "D" we see a definite similarity between the curved line above the line CD and the



original pipe throat AB. The curve from CD is constructed for the same purpose. A particle of air moving from C to D, as the wing passes through it, must travel further (over the curve); therefore, it must travel faster than it would if the line from C to D were not curved. Because this air must move faster, its pressure decreases, creating an area of reduced pressure (partial vacuum) on top of the wing. Since this partial vacuum is on top of the wing, the air under the wing, which is still at 14.7 pounds per square inch, tries to move into this partial vacuum. In its at-

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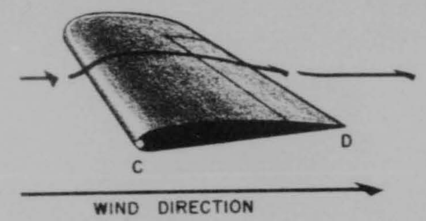


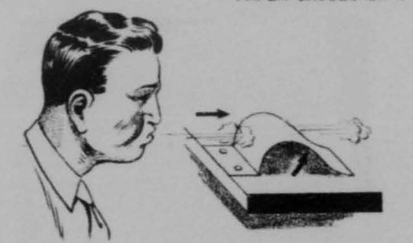
tempt to do this it presses upwards on the bottom of the wing. This lifts the wing and the aircraft leaves the ground.

This may be illustrated with a simple experiment: Take a plain piece of typewriter paper. Clear off enough of the edge of a table for this piece of paper. Now fold this piece of paper back about one inch from the end. Open this fold and place the paper on the table with the end nearest the fold near the edge of the table. It should correspond to this diagram. You will now notice that the paper from the fold (E) to the far edge (F)

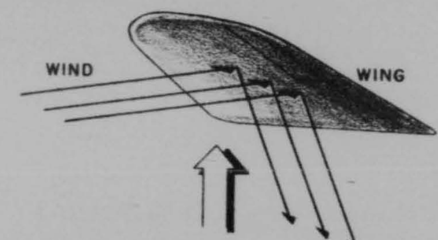
is curved like the top of the wing from C to D. Now blow moderately in puffs (not steadily) parallel to the top of the table over the top of the paper. You may be surprised to see that, instead of flattening against the top of the table, the paper tends to raise itself and, if you have a piece of soft, pliable paper it may nearly stand straight up. It is the Bernoulli idea again—high relative velocity and reduced pressure over the curve; standard pressure under the paper; the standard pressure pushes the paper up.

We have now seen where about two-thirds of the normal lift of an aircraft wing origi-

HIGH VELOCITY OVER TOP SURFACE OF PAPER CAUSES LIFT.



nates. Since the propeller also is an airfoil, about two-thirds of its lift also arises from this principle. The other one-third of the lift on an airfoil comes from the impact of the relative wind on the wing. If a flat rock is thrown across the surface of a lake, it skips along the surface as long as it maintains enough speed. Its lift comes from the force of its impact with the water. In like manner the wing of an aircraft moves through the air at a certain angle of attack: the angle of the chord of the wing to the direction of the relative wind. The wing, therefore, forces the air, which it strikes on its under-side, downwards; in turn, it is forced upwards with an equal and opposite force. These two components of lift, (1) that arising through the creation of a partial vacuum over the curved top of the wing, and (2) that amount arising from deflecting some air downwards—make up the total lift supplied by an airfoil (in this case the wing).



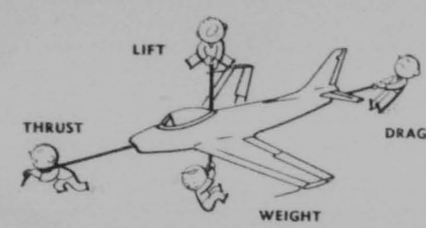
So far, two of the four forces on any aircraft in flight have been explained. The engine, through the propeller action, provides thrust, which pulls the plane ahead. This forward motion builds up the amount of airflow over the wing and creates enough lift to raise the aircraft. In direct opposition to these forces there are two others—weight and drag. Any aircraft has weight, which must be overcome by lift. Drag is the force which is the greatest deterrent to flight. Engineers have been trying for years to overcome drag in one way or another. Because air is an invisible substance it is hard to visualize the effect of drag, or to realize that the air could drag over the surface of an aircraft with so much effect that five and six thousand horsepower engines are necessary to move one fighter aircraft through the air. But this is true! Let us use the example of the effect in water again.

A person standing in water, who lowers his hand from shoulder height slowly to and into the water, feels little drag when the hand reaches the surface of the water and passes through it. However, if he lowers his hand smartly, he hits the surface with a solid slap; the harder the hand is brought down, the harder the slap. This is due to the noncompressibility of water at high speeds. The same is true in the air. At speeds up to 100 miles per hour, drag is not a major problem; but as one moves faster and faster through the air drag increases as the square of velocity. Then, when the speed of sound, the compressibility limit of air, is reached, a new set of problems arise and drag becomes the major problem of flight.

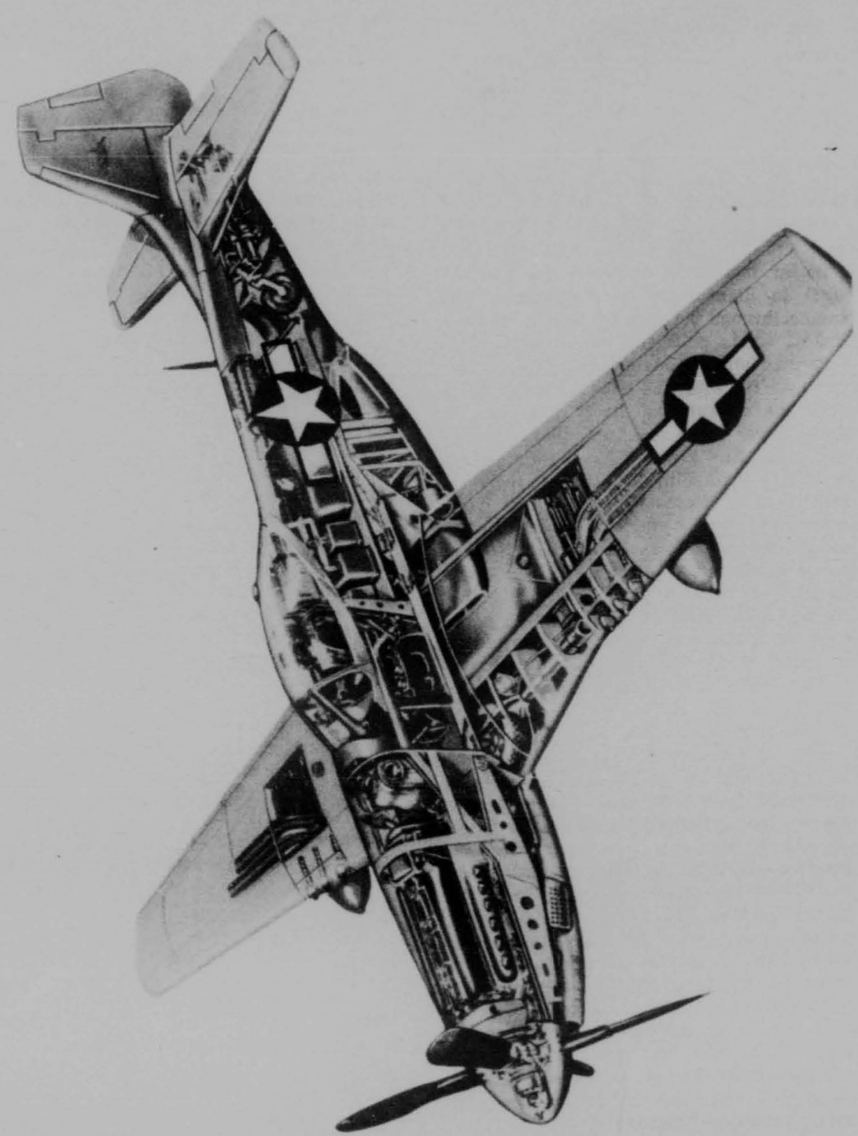
There are many kinds of drag. "Profile" drag is the resistance, or skin friction, due to the viscosity (stickiness) of the air as it passes any surface of the aircraft. This also is in combination with a "form" drag which is due to the eddying and turbulent wake of air left behind. Profile drag is just pure resistance to the movement of the aircraft through a viscous medium.

"Induced" drag, another type, is the drag component of the aerodynamic force which results from the downward velocity imparted to the air by the wing as it meets the relative wind. Its existence is unavoidable when the wing is used to create a lift force. The total drag of the wing is the sum of the profile drag and the induced drag.

Profile drag and induced drag are forces which must be accepted in part, because they result from useful causes. A third type, "parasite" drag, is sheer waste, however unavoidable. Parasite drag is caused by elements of the structure of the aircraft that do not contribute to lift. It is made up of two components: (1) skin friction, and (2) turbulence and eddying resistance. Skin friction is due to the viscosity of the air; turbulence is caused by any departure from streamline flow about the parts of the aircraft. Parasite drag is usually considered to be the sum of all the resistances except those of the wings. It includes not only the drag of the fuselage, landing gear, tail surfaces, tail wheel, and bracing, but in addition the interference drag between these parts of the aircraft. Aircraft engineers have done everything possible to reduce parasite drag. Landing gear is retracted into the wings or fuselage. All bracing is within the wing or fuselage itself—full cantilever. Nacelles are carefully streamlined, and cowling is designed to reduce



FORCES ON AN AIRPLANE IN FLIGHT



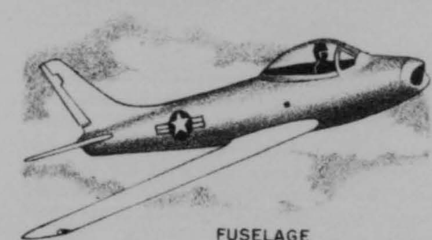
resistance to a minimum. All other protuberances are eliminated or faired into the main structure. The modern high-speed aircraft has very little parasite drag.

In summarizing the theory of flight to this point the four forces on an aircraft in motion have been discussed: (1) lift, (2) weight, (3) thrust, and (4) drag. An understanding of these four conditions of flight is the first requirement.

SECTION II - AIRCRAFT STRUCTURE

Having learned how an aircraft overcomes gravity, one may proceed to the study of how an aircraft is constructed. The aircraft is probably the most complex device constructed by man. One reason for this complexity is that it must be built to do so many things. One engineer would like to build the plane for speed, sacrificing other considerations; another manufacturer prefers to build the plane for load-carrying ability; a third wants safety, and so on. The final aircraft must represent a compromise. One often hears people ask: "Is the F-84 better than the F-80?" There is no direct answer to any of these questions. Each aircraft is built to meet certain desired specifications. Like the knife, fork, and spoon, neither is better than the other in general; one is better than the other for a specific use, i.e., the knife for cutting; spoon for soup; fork for solid foods. And so with aircraft. The B-36 is a splendid long-range, high-altitude bomber; the F-86 is a good, high-speed, medium-range fighter, etc. Each has its own utility.

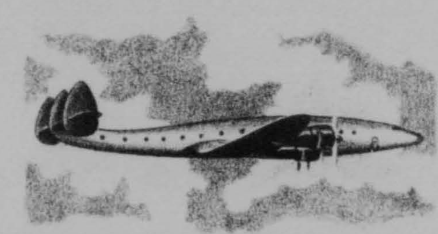
When specifications have been laid down for a certain type of aircraft, designers seek to create a product which will best fulfill all requirements. First of all lift must overcome weight, and thrust must overcome drag. The two most important parts of the aircraft are readily seen to be the powerplant and the wing. The powerplant will be discussed in a following section.



FUSELAGE

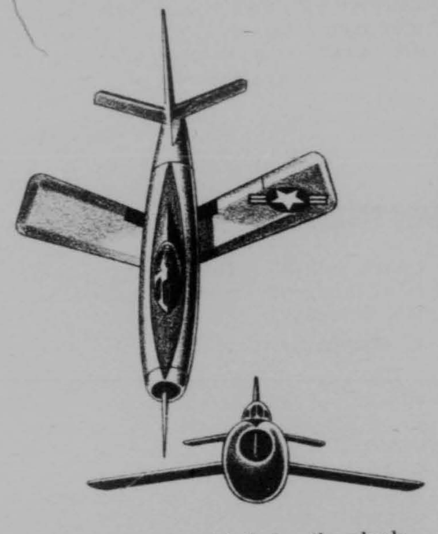
1. FUSELAGE

The wing is the primary lift surface. All lift does not come from the wing; but, as the "flying wing" type of aircraft ably demonstrates, the wing could function as an entire airframe itself. The tail section, empennage, of an aircraft carries a certain amount of the load, but it is primarily a stabilizing implement. In some cases the fuselage itself is designed along airfoil lines, and does provide direct lift to the aircraft.



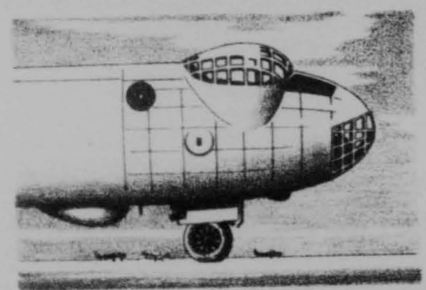
The Lockheed "Constellation" (C-121) has a "humped-back" fuselage. This is due to the fact that the top of the fuselage is curved to the same airfoil specifications which were originally used on the upper wing surface of the very successful P-38 "Lighting" of World War II. Some modern fighters incorporate "fuselage" lift into their design, but further discussion on this feature may be omitted because it is not generally used.

The normal fuselage is not a lift device. On a modern fighter like the F-86 the fuselage must house the pilot, engine, radio equipment, guns, much of the fuel, a large



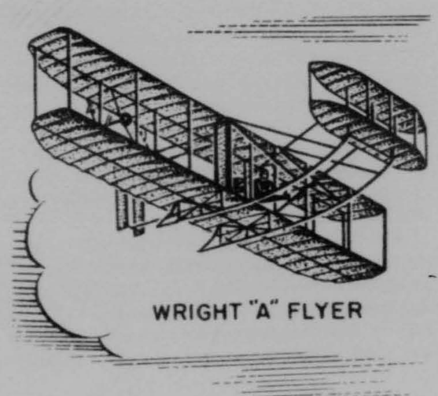
air scoop and exhaust tail pipe, the wheels—in fact almost everything—because the high-speed thin wing of that fighter is too small to have room for anything. The fuselage, then, is a necessary body cleanly streamlined over all these items and designed to afford as little drag as is possible.

Bombers and transports have an entirely different type of fuselage. It is justly called the "cabin." Today it might even be called the "the village." The fuselage of he B-36 is nearly 200 feet long (two-thirds of the length of a football field). In this fuselage there are four bomb bays, two large enough to serve as hangars for parasite fighter aircraft (F-85 type). The forward compartment is for the pilots, engineers, navigators, bombardiers, radar operators, and their equipment. Connecting the forward compartment and the center (fire-control) section is an 85-foot tunnel with a dolly for carrying a crew member from one end to the other. Far in the rear is the tail gunner's domain. This tremendous fuselage is the major bulk of the B-36. Aerodynamically it is one huge source of drag which must be overcome by the engines. Designers do what they can to streamline and reduce the size of the fuselage; but they can not exceed specified requirements.



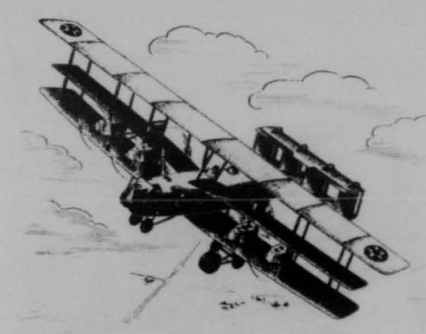
2. WING

If the details of fuselage construction seem limiting, study of wing characteristics show that those problems are relatively insignificant in comparison. The Wright brothers found out that the wing must do more than deflect air downward with its lower surface; so they warped the wing of their "flyer."



WRIGHT "A" FLYER

Through years of experimentation and development, wings became thicker and more curved. Early aircraft had several parallel wings. There were biplanes, triplanes and even quadriplanes. Because of the inability of manufacturers to build internally-trussed wings, these multiwinged aircraft were held together with wire and struts.



Barling Triplane, 1923.

As speeds increased it became imperative to cut down on this external construction, which was creating considerable drag. Also, as speeds increased, the air flow over one wing began to interfere directly with the air flow over another, and interference drag became an important concern. This eventually led to the monoplane with full cantilever construction. The monoplane was the answer to the elimination of most of the interference drag, and the cantilever construction permitted clean surfaces. But by the time the airframe had reached this stage of development power-plant manufacturers were putting out engines which were capable of driving the aircraft faster and faster. The design of the single wing itself had to be modified.

Wing Development

There were two general channels of development which could be pursued in order to change the planform of the wing. The first was to change the "aspect ratio." Aspect ratio is the ratio of the span to the mean chord, and is determined mathematically by dividing the span squared by the wing area.

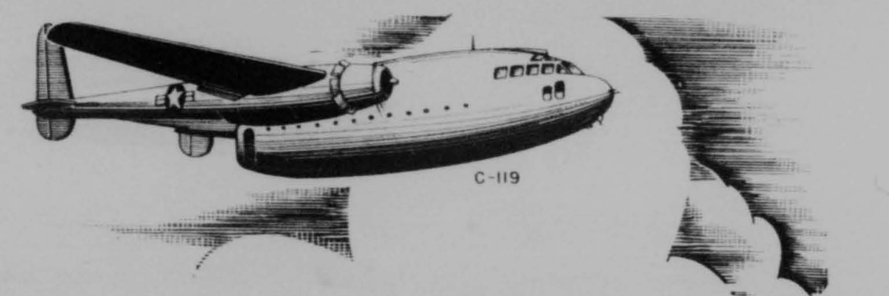
A second system of changing the plan form of the wing is by "tapering" the wing. This has led further to such innovations as "swept-back" wings, and "swept-forward" wings, "inverse" tapered wings and "delta" wings.

The airfoil cross-section of the wing itself has changed with the increase in speed. At first airfoils were curved on top and on the bottom. (Figure 2-1.) Later the bottom of the wing was kept straight and the upper surface was curved higher. (Figure 2-2.) Then as aircraft were constructed larger and larger (B-24 for example), the wing curve was increased considerably to support the heavy load on a relatively small wing area.

High Speed Wings

At the present time, with the advent of jet powered aircraft, aircraft capable of very high speeds, wings had to be designed which slit the air cleanly on the "laminar" flow pattern (Figure 2-3). The center of lift was moved further back, and the leading edge of the wing was made knife-like. Furthermore, with present aircraft approaching the speed of sound, and with the actual air-flow over many airfoil curves already at sonic or supersonic speeds, even though the airframe itself may be below Mach 1, wing design must become more and more critical. Very high speed wings are thin, usually swept-back, and knife like.

This creates other problems in wing construction. The landing gear, fuel cells, arma-



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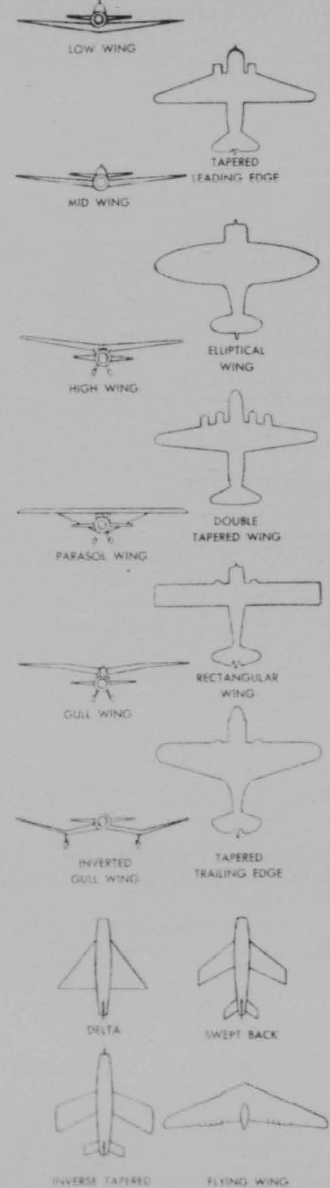


Figure 2-1

ment, and engine nacelles were in the wings of most World War II aircraft. The new thin and stubby design changes this conventional plan. On some new planes, and undoubtedly on most future ones, the landing gear and armament will have to be fitted into the fuselage. Jet engines lend themselves readily to wing-root or fuselage mounting, because they require no propellers. And, because the wings are thin and small, even the fuel cells must be in the fuselage, with auxiliary tanks on the wing tips.

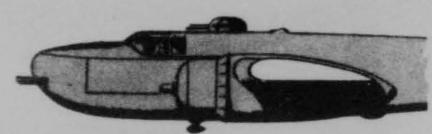


Figure 2-2

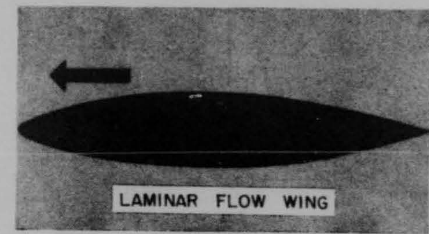


Figure 2-3

Wing Loading

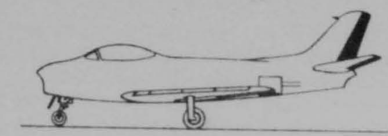
Throughout this evolution of the wing another factor has been changing—the wing loading. Formerly the weight per square foot of wing surface was quite low—less than 20 pounds per square foot. Until a few years ago a wingloading of 39 pounds per square foot was regarded as maximum. Today, with the use of high-lift devices, wing loads of over 60 to 1 are not uncommon.

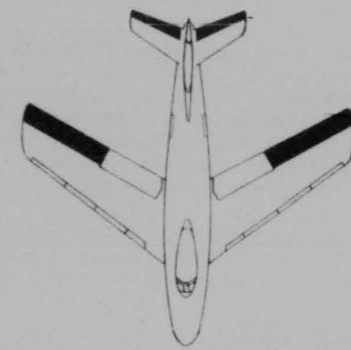
3. CONTROL SURFACES

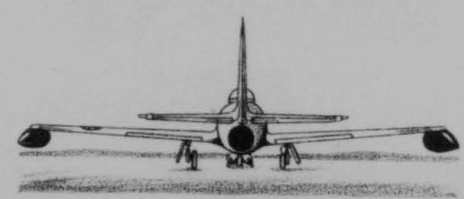
Ailerons (Elevons)

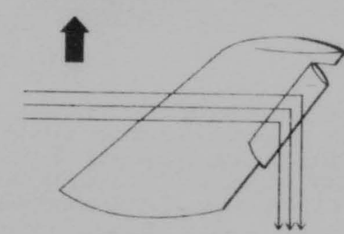
The main part of the wing provides lift, but on each wing there are other surfaces—control surfaces, and lift/drag devices. The principal control surfaces are the ailerons, elevators, and rudder. The aileron is a hinged, movable portion of the trailing edge of the wing, usually near the wing-tip. Its purpose is to change the airfoil characteristics of the wing to increase, or decrease, lift in order to raise or lower the section of wing to which it is attached. The two ailerons are rigged to work in opposite directions. When one raises the right wing, the other lowers the left wing. This causes the aircraft to bank which results in a turn to the left.

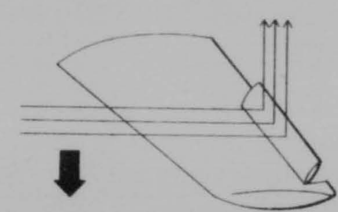
It was stated earlier that the greater the curve on the surface of the wing the more lift this wing will create. Therefore, when the aileron is lowered it increases the curve, therefore lift, of that section of the wing. While one aileron is lowered, the other is raised. This raised aileron becomes a drag device which spoils the lift of that wing sec-





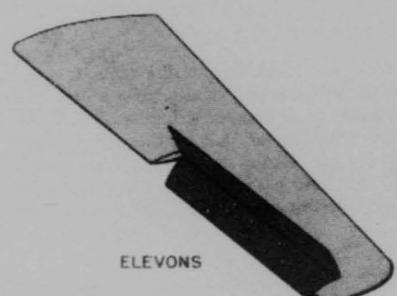






tion causing it to lower. In level flight the ailerons trail, and fit into the normal wing section creating neither lift nor drag. In high-speed flight it is necessary that the boundary layer of air flow smoothly over the entire wing surface. On some wings the ailerons have been slightly "cusped" to aid this flow of boundary-layer air. This, in turn, creates a strong pressure area which tends to hold the aileron in the "trailing" position. This pressure at times may be so great that the pilot would be unable to actuate the aileron controls with an unassisted lever. Some jet aircraft have incorporated a system of hydraulic or mechanical boost to aid the pilot.

Such problems have caused engineers to try other means of achieving lateral control. On many new aircraft they are using el-



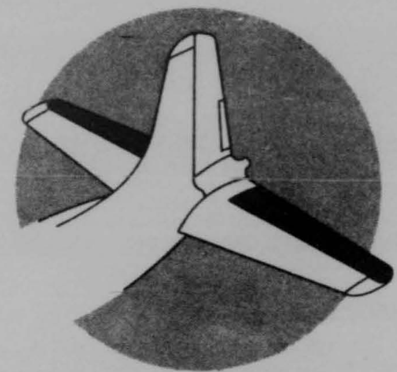
evons. Elevons perform the function of the aileron by creating drag on one wing, causing it to drop. In general, elevons are flat surfaces which are raised or lowered (or both) from the normal surface area of the wing.

Elevator

The second control surface is the elevator. The elevator is attached on the trailing edge of the horizontal stabilizer. When it is raised, it forces the tail of the aircraft down; when it is lowered, it forces the tail up.

Rudder

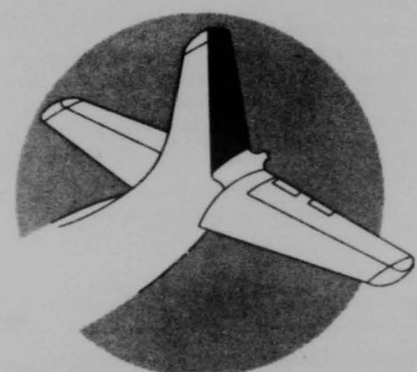
The third control surface is the rudder. It is attached on the trailing edge of the vertical stabilizer. The rudder is moved left or right. When it is moved to the left it



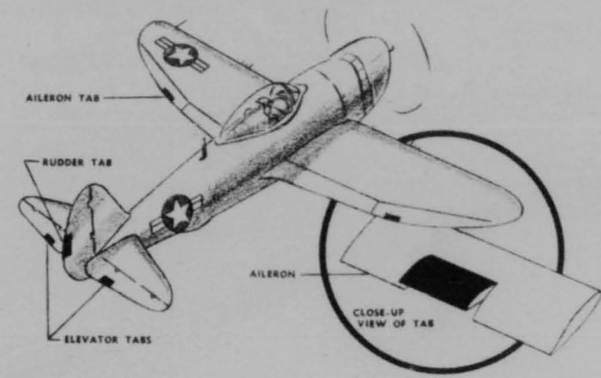
forces the tail to the right turning the aircraft to the left. In normal flight it trails the stabilizer.

4. CONTROL TABS

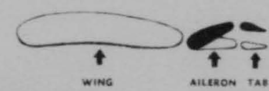
Because the forces of high speed flight are so great, and because some modern aircraft are so large, it requires considerable force to actuate these control surfaces. As a result greater use is being made of control tabs. A tab is a small surface attached to the trailing edge of the normal control surface. This small surface is moved by a fixed control which sets it at the desired angle with respect to the control surface itself. When the tab, for example the rudder tab, is moved to the left, it will force the rudder to the right (by virtue of the dynamic force of the impact of



TRIM TABS

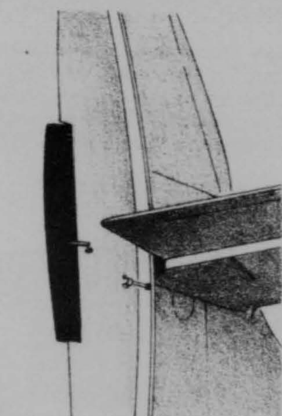


THE LOCATION OF TRIM TABS



OPERATION OF TRIM TAB

relative wind over the tail of the aircraft). By forcing the rudder to the right, it causes the tail of the aircraft to be moved to the left. When the empennage is moved to the left, the aircraft moves to the right. This same chain of events occurs with respect to



the elevator tab and the aileron tab.

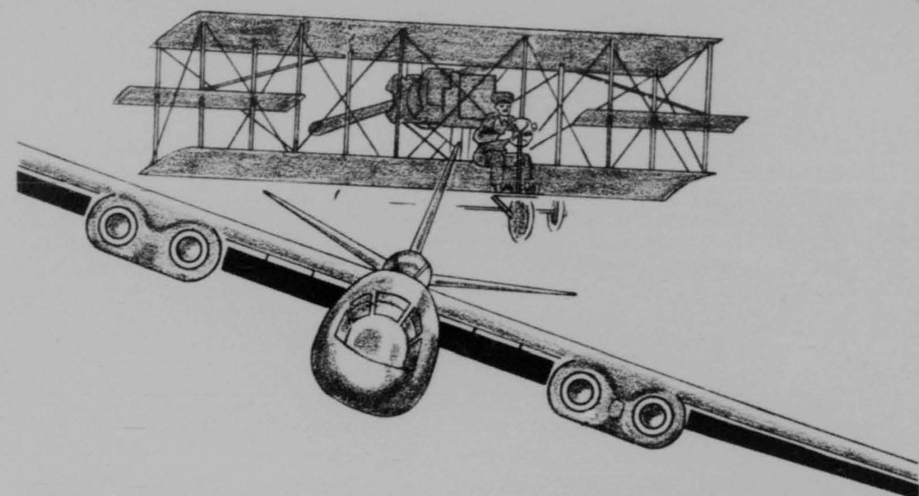
This is not the only use of the tab. It is perhaps not even its principal use. Tabs are primarily used to trim the aircraft in "straight-and-level" stabilized flight, which will be discussed in a later section.

5. HIGH LIFT DEVICES

The wing loading of modern aircraft has increased to such a point that it is, in some cases, as high as 65 to 1. This can be aerodynamically sound as long as the aircraft maintains high speed at all times. However, the normal aircraft must conform to current operational requirements of run-way length and landing speeds. A high wing loading means that aircraft must land at very high speed unless something is done to increase lift at lower speeds. This is done with the use of flaps and slots.

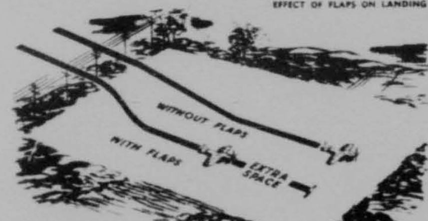
Flaps

Conventional Flaps. Flaps are airfoil sections at the trailing edge of the wing. They add to lift by increasing the wing area and

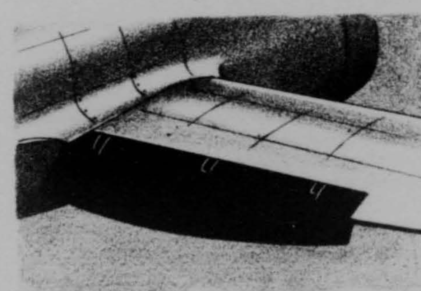


its airfoil curve. They also increase drag considerably. Flaps have been very useful on conventional aircraft for the purpose of reducing landing speed, and increasing the rate of descent.

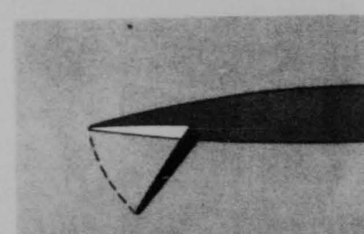
EFFECT OF FLAPS ON LANDING



There are three common types of flaps. The conventional flap is a rear section of the wing itself which is hinged and may be lowered. This large, flat surface lowered at an angle of 50 to 70 degrees produces considerable drag which spoils the lift of the airfoil and permits the aircraft to glide to a landing at a very steep angle. When the flaps are lowered 25 to 35 degrees they extend the curve of the airfoil enough to create additional lift. This permits the aircraft to land at a slower air speed than would be possible without flaps.

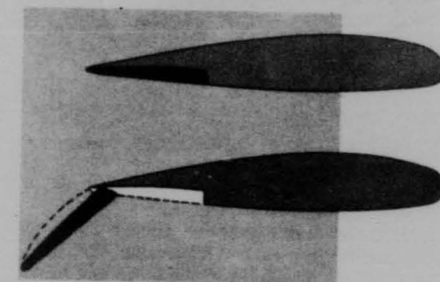


Split Flaps. Conventional hinged flaps were found to create a higher ratio of drag to lift than was desired on some type airfoils; so split flaps were devised. The lower section of the wing is the only part which is hinged,



and the trailing edge splits. This type of flap does not alter the upper airfoil curve of the wing; but it does provide the same amount of drag as the conventional flap.

Fowler Flaps. Some aircraft, especially heavy aircraft, need to gain considerable lift in order to slow down before landing. Fowler

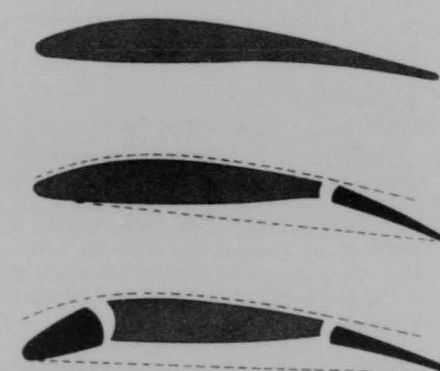


flaps have been constructed to do this. They combine the features of normal flaps and split flaps. Fowler flaps are a type of split flaps. The flap (lower) portion of the wing moves backwards on guides without lowering from the wing. The rearward movement of this large surface, first of all, adds to the wing area itself. Then, after the flap has begun to move to the rear it is guided downwards and farther back. Fowler flaps may be lowered as much as 70 degrees from the chord line; and, because they increase the area and airfoil curve so much, they increase total lift considerably. They represent the most useful high lift/drag device available at present.

Certain advances in modern design have had an important effect on flap design. The old, familiar DC-3 (C-47) uses the split flaps. To increase the flap area, the section was continued under the fuselage from wing-root to wing-root. This innovation gave the DC-3 a long flap area extending unbroken from aileron to aileron.

The increase in size and number of engine nacelles has made it necessary in many large aircraft to hinge the lower rear section of the nacelle so that it may be lowered with the flaps, as an integral part of the flap.

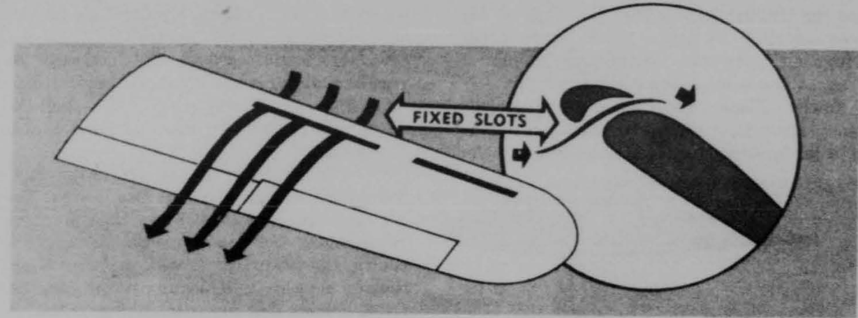
Furthermore, since flaps are now so necessary for high wing-load aircraft, the total area of the flaps must be increased. This has led to the development of flaps from wing-tip to wing-tip, which consequently blocked out the area conventionally assigned to the aileron. This has been another reason behind the development of the elevon as a lateral control. The elevon works as efficiently in



BASIC AIRFOIL (THIN, HIGH-SPEED WING)

DOTTED LINES SHOW EFFECTIVE CAMBER WITH TRAILING EDGE FLAPS PARTIALLY DOWN.

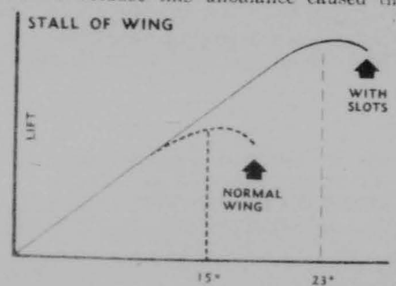
DOTTED LINES SHOW EFFECTIVE CAMBER WITH BOTH LEADING EDGE AND TRAILING EDGE FLAPS PARTIALLY DOWN.



the center of the wing as it does at the trailing edge, and therefore lends itself as a suitable substitute for the aileron.

Leading-edge Flap. A major function of the wing flaps is to increase the airfoil curve of the wing. Research during the past several years has shown that a leading-edge flap would also increase lift, because it, too, would increase the forward part of the airfoil curve. The F-86 has these leading-edge flaps. This consists of a section of the leading edge of the wing which may be moved forward and downward in the same manner as the Fowler flap.

Flap Control. Flaps are used for both landing and take-off. They are sometimes used in flight. Their effect is so great on the flying characteristics of the aircraft that a very efficient control and activating system must be employed whether it be electrical, pneumatic, or hydraulic. One of the early weaknesses of flap operation was that the system would not always "balance", i.e., one flap (left or right) would come down before the other one. The results were sometimes disastrous because this unbalance caused the



plane to roll over. This "balancing" of flaps is now well regulated.

Slots. Leading-edge flaps appear to be a refinement of an early device called the wing "slot." The slot is built in the wing just back of the leading edge a few inches, and extends along the wing, usually in the outer section. It is cut through the wing from the lower surface to the top. During normal flight it plays no part in the over-all airflow pattern; but as the wing approaches the stall angle it permits air to flow through behind the leading edge, improving the low-speed characteristics of the wing.

Slat. In some cases, principally on small low speed aircraft, a slat is built into the leading edge of the wing, which automatically moves out in front of the wing when the wing approaches a stall. By moving out ahead of the wing the slat performs the same function of a slot.

6. LANDING GEAR

Evolution of the Landing Gear

The Wright brothers had few problems when it came to devising a landing gear. For a light, low-speed aircraft a pair of skids was a satisfactory solution. For today's fifty-ton 600 mile-per-hour bomber, with its swept-back, thin wings the problem of designing a light, but strong, landing gear is very complex.

As aircraft speed and weight increased the skid became impractical. It was replaced by a pair of wheels placed side by side ahead of the center of gravity of the aircraft. For many years thereafter the empennage was supported by a tail-skid, which in turn was

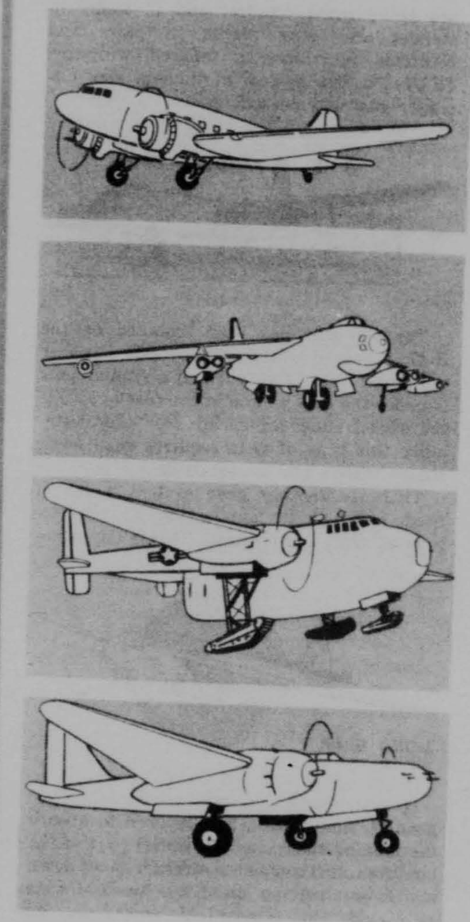
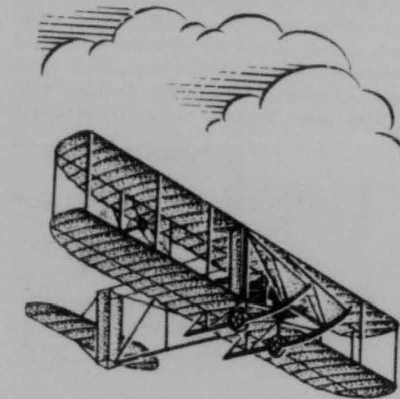


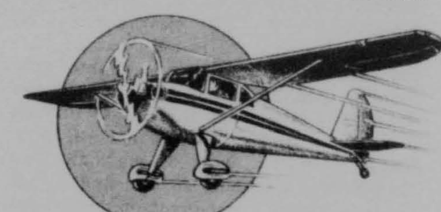
Figure 2-4

replaced by a 360 degree swivel tail-wheel. This arrangement became standard on all land-based aircraft for so many years that it became known as the "conventional" type of landing gear. (In this chapter it will not be possible to cover the details of landing gear construction. The discussion will be limited to the type of gear.) The landing gear



had to be rugged enough to sustain the shock of ground contact, and high enough to keep the propeller from striking the ground when the tail was raised during the take-off run.

Then as aircraft speeds increased and drag became a major factor, the wheels of the plane were faired over with "pants" to streamline them, and the landing gear struts were inclosed in a smooth sheath. The next



FIXED GEAR

change was the development of retractable landing gear. This was a major advance in aircraft engineering, because it completely eliminated the considerable drag created by the landing gear. It was a few more years before the tail wheel was made retractable. This eliminated all landing-gear drag.

Just before World War II new aircraft were designed with the main gear behind the center of gravity, and with a small wheel under the nose of the plane. The earlier, conventional gear had employed three wheels; but in spite of this, the new system became

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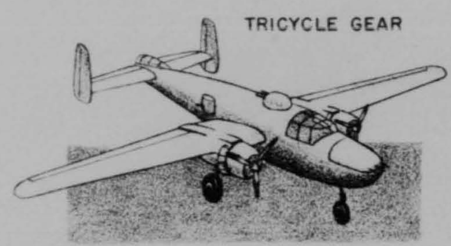
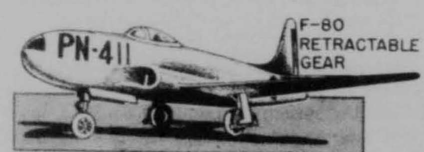
popularly known as "tricycle" gear. In many ways this was a big improvement over the conventional type of gear. First of all, the fuselage was now level with the ground at all times. It also made landing easier, especially cross-wind landings. Before long, tricycle gear became more conventional



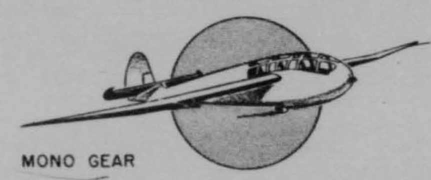
than the old system. Nearly all present aircraft utilize this system. At first it was necessary to build the tricycle gear quite high because high-power engines utilized very long-bladed propellers which had to be kept above the ground with enough margin to take into account tire failure and the 10 to 15 inch drop on the blow-out side. This high, complicated gear added considerable weight to the air frame itself.

With the advent of jet propulsion engineering for propeller clearance was no longer necessary. It meant that on jet-propelled aircraft a shorter and lighter gear could be used. But before aircraft designers could relax as a result of this easy solution to a major problem, a new one began to plague them. The wing of the high-speed aircraft was becoming so thin and so far swept-back that it was becoming almost impossible to retract the wheels into the wing. (Originally, in an effort to broaden the base of the gear so that landing an aircraft would be easier and to prevent interference with the bomb bays in bombers, the wheels were put out in the wings.) This problem is currently being met in three ways: wheels are being retracted into the fuselage; wheels are being made smaller, and in some instances are being placed in pairs and retracted into inverse, tapered wing-tips (F-91); a new system of tandem and outrigger gear has been devised.



Tandem gear has been installed on the B-47. A pair of wheels, side by side, is under the nose of the fuselage; and a similar pair is under the rear section of the fuselage (like the wheels under a bicycle). For lateral stability this type of gear requires small, outrigger wheels under each wing.

There is another gear system which is used, although its application on heavier-than-air craft is infrequent. This is the mono-



gear. A small nose-wheel is used to absorb the landing shock and the initial part of the landing roll. Then as the aircraft slows down and loses all flying speed the fuselage rests on a skid. This is adaptable so far only on light aircraft. With weight and space considerations so important today in aircraft design, it is possible that heavier aircraft might adopt this system. The nose-wheel would sustain the impact of landing and the actual landing on a keel skid would not be hazardous.

This leaves the evolution of the landing gear where it started, because the mono-gear is only once-removed from the skid itself.

7. AIRCRAFT STABILITY

Definition

An acceptable aircraft must be stable in flight. This may be defined as the tendency of an aircraft to return, without the aid of the pilot, to a condition of steady flight when it has been disturbed. There are two general classes of stability: static stability and dynamic stability.

Static Stability

An aircraft is statically stable if, when disturbed from a condition of steady flight, an unbalanced force is automatically set up in the proper direction to return it toward its original attitude of steady flight. The airplane is statically unstable if the unbalanced forces direct it still further from the original attitude. If no unbalanced forces are set up, the aircraft is said to have neutral static stability.

Dynamic Stability

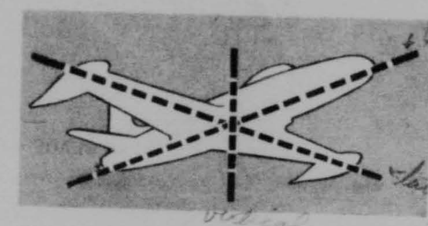
When a statically-stable aircraft is disturbed from a condition of steady flight, it is restored to its initial attitude by a built-in force. Ordinarily, this force will carry the plane beyond its original attitude. Then, since it is statically stable, a force will be set up in the opposite direction, causing the aircraft to swing back again. This may be repeated several times, the aircraft oscillating past the neutral position with a motion similar to that of a pendulum. If these oscillations die out and the airplane returns to its original condition of steady flight, it is dynamically stable. If the oscillations increase in magnitude, the aircraft is dynamically unstable, and if the oscillations continue unchanged, the aircraft has neutral dynamic stability.

It should be noted that dynamic stability is dependent upon static stability; that is, if it is statically unstable it will not have the opportunity to demonstrate whether or not it is dynamically stable, since the forces necessary to produce the oscillations will never be set up in a statically-unstable aircraft. An aircraft may be statically stable and dynamically stable, or it may be statically stable and dynamically unstable.

Stability is essential in any aircraft. An unstable plane may be flown all right; but it will require constant control. A stable aircraft, however, will remain steady in level flight, without the necessity of constant control; furthermore, if deflected from level flight by a gust of wind, a stable plane will return to level flight itself without requiring that the pilot apply sudden correction.

Axes of An Aircraft

An aircraft has three axes, and all motion of the aircraft is around one or more of these



axes. The lateral axis is along a line from wing-tip to wing-tip through the center of gravity. Motion about the lateral axis is called "pitch," and is controlled by the elevators. This lateral motion causes the plane to climb or descend.

The longitudinal axis is along a line from the nose to the tail through the center of gravity. Motion about the longitudinal axis is called "roll," and is controlled by the ailerons or elevons. Longitudinal motion causes the plane to turn right or left.

The vertical axis is along a line drawn vertically through the center of gravity and perpendicular to both the longitudinal and lateral axis. Motion about the vertical axis is called "yaw," and is controlled by the rudder.

8. PROPELLERS

We have already mentioned that a propeller is an airfoil, and as such it sets up forces the same as any other airfoil. When the Wright brothers were planning their aircraft, they tried to find out if any scientific data existed governing the use of propellers. They found that for aircraft propellers there was no reliable data. They even turned to scientific data on steamship propellers and found that there was almost nothing on this subject. Because of this lack of material on

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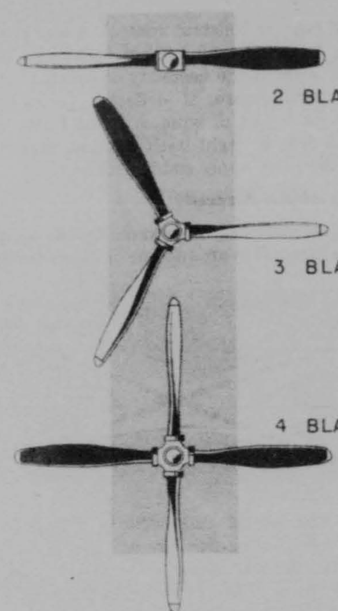
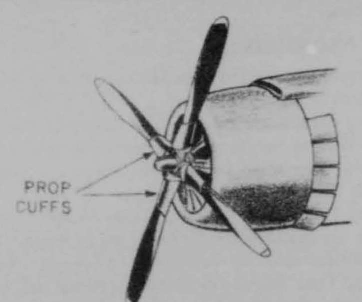


TYPICAL PROPELLERS

propellers, they had to start from scratch and work out their own experimental types. Beginning with these experiments the development of the aircraft propeller has been as spectacular as the development of the aircraft itself.

The function of the propeller is to provide thrust. It does this in the same manner that any airfoil functions. In addition to creating thrust, the propeller is used in some cases to aid in cooling the engine. Cuffs are added to the inner portion of the blade to increase the volume of air passing over the engine. The propeller also forces a flow of air over the tail surfaces which is a help in taxiing and low-speed flight.



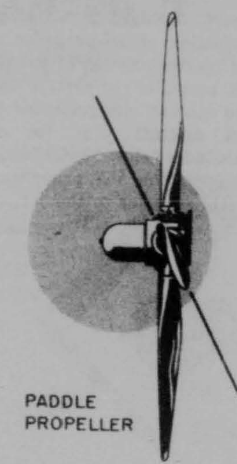
There are many types of propellers. A one-bladed propeller is efficient but has not been adapted for general usage. During the first three decades of powered flight, the two-bladed propeller was the conventional type. Then as engines became more powerful, longer and larger propellers were required. Because the length of the propeller blade must be limited by the length of the landing gear, height of the engine above the ground, etc., an alternative to the long-bladed propeller was required. This led to the use of three, four, and even five-blade propellers, and also to the use of contra-rotating propellers. Each of these new designs was evolved to utilize the increase in power of new engines.

The length of the propeller blade was not limited entirely by the landing gear, etc., but by the fact that the longer the blade, the faster the tip speed is. As this speed approaches the speed of sound, the tip, like any other airfoil, is affected by compressibility shock waves which reduce its effectiveness appreciably. A shorter, multi-blade propeller does not reach this sonic barrier as rapidly as the longer blade propeller.

For many years it was believed that the tip of the propeller should be tapered. Until the end of World War II most conventional blades were tapered. However, during the war the paddle-propeller became familiar, and following this development the square-tip propeller became widely used. This square-tip blade is most efficient with high-power engines for high-speed and high-altitude flight.

Conventional propellers have all been straight from tip to tip. But recently a swept-back type has been designed. It has been developed for near sonic-speed operation.

Most propellers are in front of the engine to which they are attached; but on some aircraft, notably the B-36, the propellers are mounted in the rear. These are called "pusher" propellers. The advantages, on the B-36 especially, are that the engine may be com-



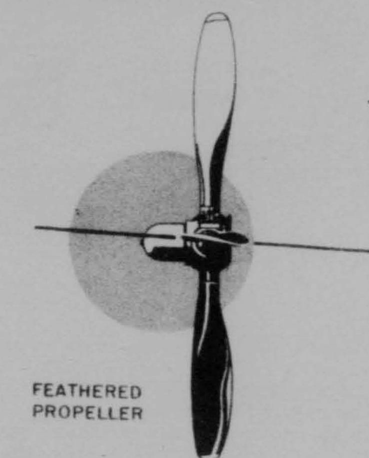
pletely housed inside the wing, and the leading edge of the wing is unobstructed by the nacelle.

No aircraft propeller would be efficient on planes flying over 100 to 150 miles per hour, without controllable pitch. Without going into detail, the reasons for this have to do with the idea of the efficiency of any airfoil with respect to its angle of attack. A fixed propeller has a certain, built-in, angle of attack. As the speed of the aircraft increases, this forward motion changes the effect of this built-in angle of attack relative to the mass of air through which it is moving. An increase in forward speed increases the angle of attack; and, as we know, the angle of attack is limited by the stalling angle. At this point the propeller loses efficiency. To cope with this situation controllable-pitch propellers have been developed.

The simplest controllable-pitch propeller is the two-speed type. It has two speeds, one for low-speed operation (take-off, climb, and landing); the other, for high-speed operation (normal cruising). This type is an improvement over the fixed-pitch propeller; but it too has limitations.

These limitations were overcome by the fully-controlled, constant-speed propeller. By means of mechanical, hydraulic, or electrical power the blade of the propeller may be set to rotate at a constant rpm regardless of the speed of the aircraft or the power applied. This gives the pilot full control over the propeller. He may move the propeller from its top rpm limit, around 2800 rpm, to full-feathering.

The ability of the modern propeller to "feather" is an added necessary feature. This causes the blades to turn with their leading



edge into the wind, when the engine is stopped. It cuts down on drag by turning the blade face parallel to the relative wind; and, even more important, it keeps the "dead" engine from rotating. In multi-engine aircraft it is sometimes necessary to stop an engine in flight. If the propeller could not "feather," this engine would windmill, with the result that it would create considerable drag, and might destroy the engine by grinding-up a malfunctioning engine.

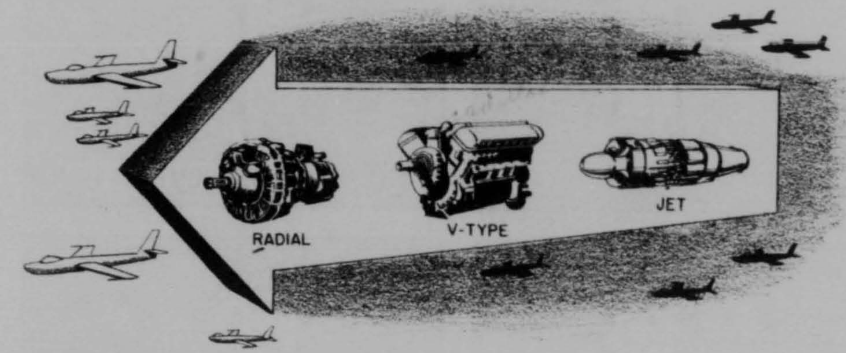
Modern propellers go one step beyond feathering. They reverse their blade pitch. Huge bombers and transport aircraft normally require long run-ways for landing. To overcome this, it is now possible for the pilot to reverse the pitch of the propellers, and then, by adding power, convert the propellers into pusher blades to slow down the roll of the aircraft. This has made it possible to stop these large aircraft in short distances.

The reverse pitch blade has become very

useful for another purpose. It can be used in flight to make it possible for an aircraft to descend very rapidly, without increasing its airspeed appreciably, from a high altitude. With large aircraft flying at very high altitudes the time required for normal let-down is considerable. By reversing the propeller the same aircraft can let down in a fraction of this time.

In summary, it might be added that the rapid introduction of jet-propelled aircraft has brought up the question of the future of the aircraft propeller. In certain usage the jet-propelled aircraft out-performs the propeller-driven aircraft. But for subsonic speeds, at altitudes below 50,000 feet, and for economical operation the propeller driven aircraft is still superior to the jet.

CHAPTER 3 - AIRCRAFT POWER PLANTS



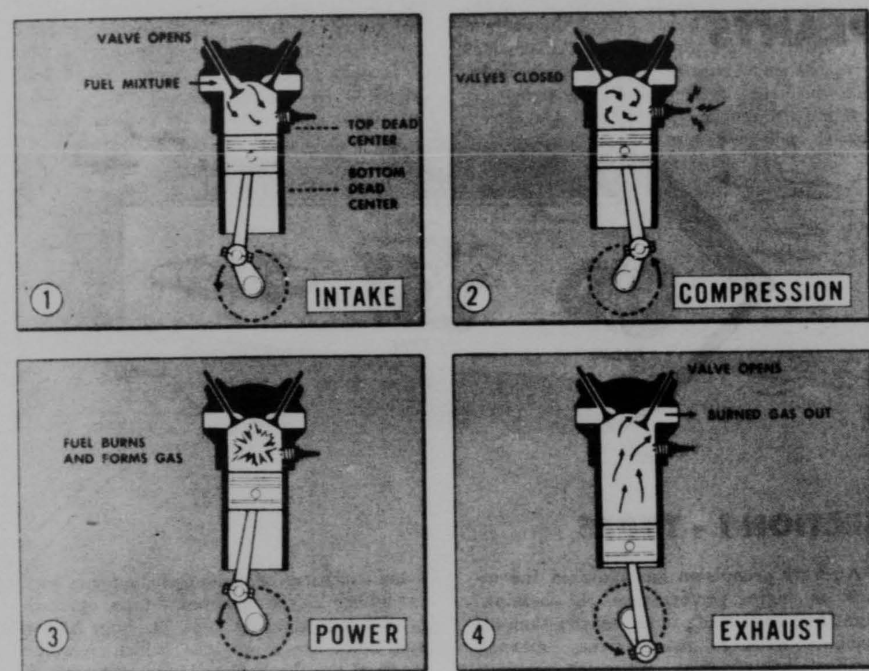
SECTION I - TYPES

Aircraft propulsion has required the utmost in engine performance. No sustained flight had been made in an heavier-than-air machine until a piston-driven, internal-combustion engine was built which combined high power with low weight. A very nearly successful flight had been made with a steam engine before the flight of the Wright brothers, but no wholly successful prototype was made. Since the time of the Wrights' first flight all sorts of engines have been used. One ingenious inventor experimented with a rotary engine. This is not to be confused with the radial engine. All parts of the rotary engine rotated around a fixed crankshaft. The propeller would then be driven by the engine, not the shaft. This engine might have been more successful in the early days of aviation if it had not used direct fuel injection, which at that time had not been perfected.

LIQUID-COOLED ENGINES

The 12-cylinder, liquid-cooled Liberty engine was the outstanding American aircraft engine of World War I and the period following. It was compact and powerful. There were many variations of liquid-cooled engines such as: inline; V-type; inverted V-type; opposed-type; fan-type; and X-type. The huge Allison and Rolls-Royce engines which powered many of the World War II aircraft are outstanding examples of the liquid-cooled engine.

An entirely different family of engines is the air-cooled radial engine. There has been considerable controversy over the advantages of one over the other for aircraft use. The liquid-cooled engine, of course, requires a liquid coolant fluid which adds additional weight. It also requires a radiator, and the necessary cooling system. However, proponents of this type of engine state that its trim, streamline configuration more than offset this additional weight. The sleek "Mustang," "Spitfire," and "Mosquito" of World War II fame bear out this statement. However, there are claims that in combat the liquid-cooled engine is perhaps more vulnerable than the air-cooled. If the coolant system of the liquid-cooled plane is damaged, the engine will fail. In other cases, it has been indicated that the life of the liquid-cooled engine is not as great as that of the radial; this in turn is countered



The piston makes four strokes during the five events which occur in a cylinder in one complete cycle of operation. Two of the strokes are inward, and two are outward.

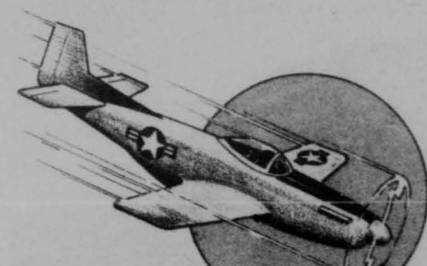
INTAKE STROKE — This stroke takes place as the piston moves out of the cylinder toward the crankshaft. During this stroke the volume within the cylinder is increasing; at the same time, the lowered pressure within the cylinder allows the fuel air mixture to be forced into the cylinder through the intake valve port, which is open.

COMPRESSION STROKE — As the piston reverses its direction and moves into the cylinder, the intake and exhaust valves are closed. The piston decreases the volume of the cylinder chamber and compresses the fuel mixture into a small space. Just before the end of this stroke, a spark from a spark plug ignites the fuel. Notice that two of the events occur during this stroke.

POWER STROKE — The fuel is now burning and as the piston again changes its direction of motion the burning fuel tends to form a large volume of gas. The pressure thus exerted moves the piston. This is the power stroke.

EXHAUST STROKE — When the piston has almost reached the bottom of the third stroke, the exhaust valve opens. Then, as the piston makes the fourth and last stroke of the cycle, it pushes the burned gases out of the cylinder. The cycle now is ready to begin again.

Figure 3-1 Four Stroke Cycle of Reciprocating Internal Combustion Engine



F-51
INLINE ENGINE

with the claim that the liquid-cooled engine runs smoother.

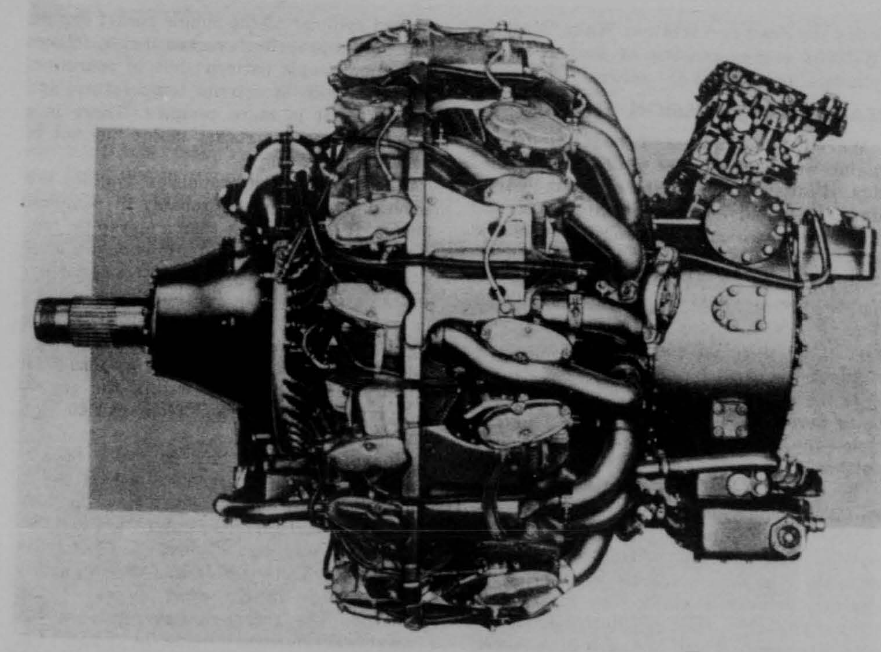
It is not necessary to take sides in this issue. Both types are outstanding propulsion units.

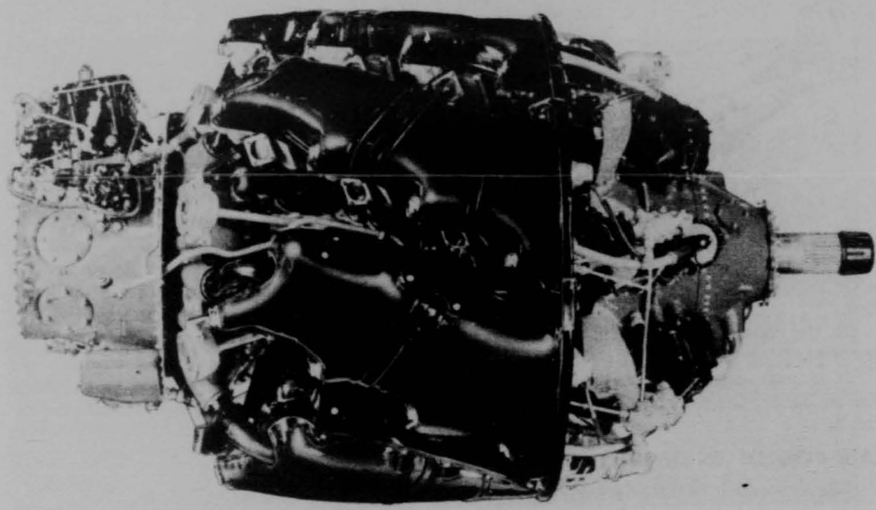
AIR-COOLED ENGINES

The air-cooled, radial engine is a product of the aviation industry. With a few exceptions (early World War II U.S. tanks) it has been used exclusively in aircraft.

The first radial engines consisted of a row of cylinders arranged around the crankshaft like the petals on a flower. As the size of the engine increased the number of cylinders increased, and the overall diameter of the engine increased until it seemed that the radial engine would reach its limit of efficiency because of its great diameter. The victories of the radical engine-powered Gee-Bee aircraft in the Cleveland Air Races, and its world speed-record flights, during the early 1930's helped the cause of the radial engine appreciably, in spite of its diameter. The perfection of the NAC ring cowling and resultant decrease in drag further aided the development of this engine. But the radial-engine designers themselves boosted their own cause best when they developed the twin-row radial.

In effect, two radial engines were harnessed in tandem to a main crankshaft.





PRATT-WHITNEY WASP "MAJOR" (4360) FOUR ROW RADIAL ENGINE.

Today the Pratt and Whitney Wasp "Major" (R-4360) engine consists of four rows of cylinders, one behind the other.

REACTION-PROPULSION ENGINES

While the development of the piston-driven engine was keeping pace with airframe design, it satisfied the demand of the industry. However, the advances in airframe construction and size which came along in the 1930's out-stripped the development in power-plants. Such airframes as that of the B-15 and B-19 indicated clearly that the engines current at that time were not powerful enough, and that there were no adequate power-plants available for such large aircraft.

At the same time a new type of engine was being developed. It incorporated an old principle—the idea of the use of reaction propulsion.

In theory there are countless types of reaction-propulsion engines. Reaction propulsion is used commonly to include jet propulsion and rocket propulsion. Strictly defined, it would include all other types of engines, because basically they incorporate the use of the power of reaction to drive pistons. The simplest motor of all is the powder-packed cylinder of the simple rocket engine. The liquid-propellent rocket motor follows the same simple pattern; but in operation, mainly because of extreme temperatures and pressures, it is more complex. There is a gaseous-propellent rocket motor but not in general use.

The types of jet-propulsion engines are several. The ramjet is probably the simplest design. It is little more than a stovepipe, convergent at each end. The pulsejet engine adds shutters to the ramjet for lower-speed operation. Neither ramjet nor pulsejet can operate from rest without added thrust. The most useful design of all present jet-propulsion engines is the turbojet. By means of the compressor and turbine within the engine this type is self-sufficient from rest to high speed.

Summarizing the various types of aircraft engines there are many others which might be mentioned. The turboprop uses the compressor-turbine combination to drive a propeller, and is an efficient engine of great importance. The turbo-ramjet uses an added ramjet stage in the after-burner of the turbojet. The rocket-ramjet combines the rocket and ramjet to provide the ramjet with

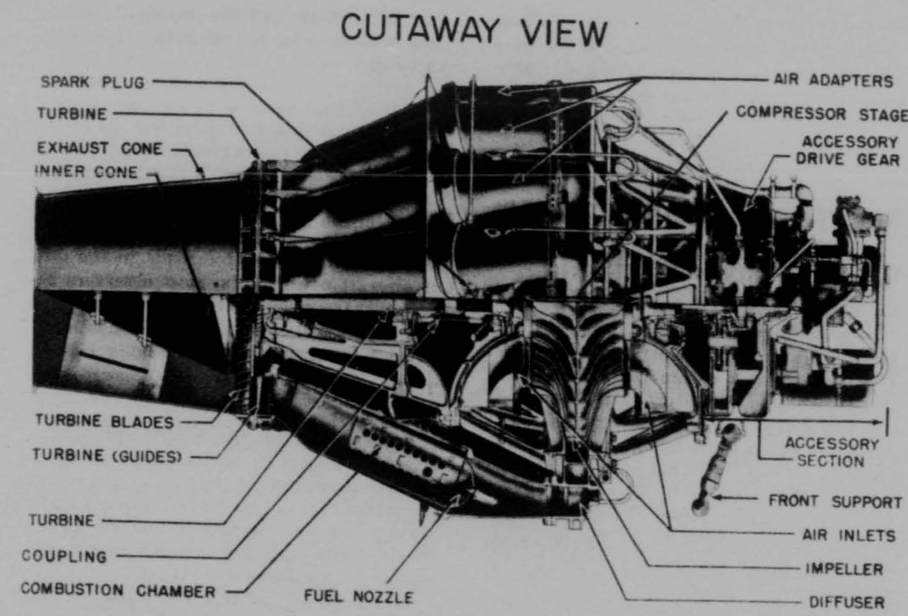
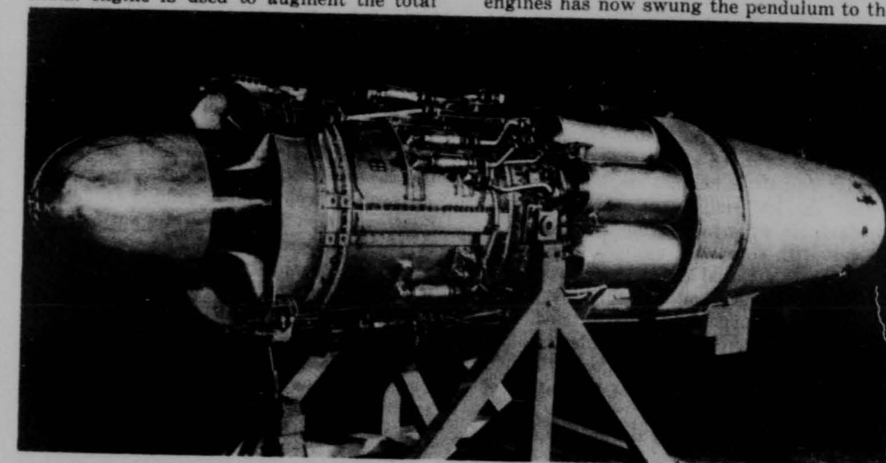


Figure 3-2 Cutaway View of Jet Engine

internal thrust from rest. Radial engines have been used as compressors coupled with a turbine. In other cases the exhaust of the radial engine is used to augment the total thrust of the power unit. Whatever the combination, or in cases where the reaction engine is used by itself, this new family of engines has now swung the pendulum to the



opposite side. The power plant has now outdistanced the airframe. Today the engine manufacturer is constantly trying to find a suitable airframe for his powerful engine. Engines of 5,000 to 7,000 pounds thrust are now in service; for full utilization they await super airframes.

SECTION II - OPERATION

1. PISTON-DRIVEN INTERNAL COMBUSTION

Both the liquid-cooled and air-cooled engines operate on the same basic principle. The piston moves within the cylinder in a four-stroke cycle. (See Figure 3-1) The successive power strokes of the many cylinders are applied in series to the crankshaft. It is this series of strokes which keeps the crankshaft moving. The crankshaft, in turn, delivers this force to the propeller. Not all the power of the engine is delivered to the propeller. The basic engine must furnish power for the operation of the accessories such as: generator, hydraulic pump, fuel pump, oil pump, and supercharger. Most of the useful power is applied to the propeller. The propeller then utilizes this power to accelerate a large mass of air to the rear. The reaction to this force moves the aircraft forward.

This operation is much like that used by a swimmer in water. A man floating on the water remains motionless. Then, when he begins to move his arms and legs, he pushes on the water; and, because the water pushes on him (offers resistance to his thrust) he moves forward.

In some instances the piston-driven engine is not used to drive a propeller. One of the first jet-propulsion engines employed a piston engine for its compressor stage. Recently considerable experimentation has been underway with compound engines. Such combinations as a radial engine and one or two gas-turbine stages, plus a turbo-jet stage with an after-burner—have been tried. This compound engine drives a propeller in addition to its jet thrust. The purpose of such a combination is for the fullest utilization of fuel.

In spite of the fact that the jet-propulsion engine has made great inroads in the field of aircraft power units, most observers believe that the piston-driven, internal-combustion engine will be used for various types of aircraft for many years to come.

2. REACTION PROPULSION

Definition

Perhaps because the reaction-propulsion type of engine is so new, a universal definition for it and for jet propulsion and rocket propulsion has not evolved. There are many texts which use reaction propulsion as the over-all term including jet and rocket propulsion as its two sub-divisions.

There also are other texts, equally as authoritative, which refer to jet propulsion as the over-all term including rocket propulsion. Fundamentally Newton's third law applies: "For every acting force, there is an equal and opposite reacting force." Here the term "acting force" means the force one body exerts on a second body, while "reacting force" means the force the second body exerts on the first. Therefore, it should follow that all engines operate on the reaction principle; and further that direct-propulsion engines are primarily reaction propulsion, and then subdivided into jet propulsion and rocket propulsion. For the purposes of this course the above definition will apply.

Reaction propulsion is defined as, "a propulsion system in which a forward motion or thrust is produced by the expulsion of propellent gases through nozzles or venturi, generally longitudinally opposed to the intended line of travel." This definition, in effect, draws a line between the reciprocating engine and the piston-driven, internal-combustion engine. Actually the piston-driven engine and the reaction engine are both internal combustion engines.

Jet propulsion is defined as "reaction propulsion in which the propulsion unit obtains oxygen (and mass) from the air as distinguished from rocket propulsion in which the unit carries its own mass and comburent material. In connection with aircraft propulsion, the term refers to a jet unit which discharges hot gas through a tail pipe and a nozzle, affording a thrust which propels the aircraft." Before proceeding further on definitions we should study the principles underlying the theory of reaction propulsion for aircraft.

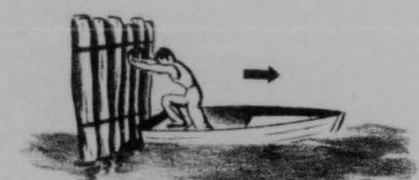
Principle of Reaction Propulsion

Although the idea of reaction propulsion is very old, many people do not realize how it is possible for an aircraft to fly without some visible means of propulsion. It is common belief that the supersonic stream of air which is emitted by the jet engine (for purposes of simplification the term "jet engine" will be used as an example of all types of reaction engines) pushes against the outside air and that this somehow pushes the aircraft along. Such ideas are wholly erroneous. If this idea were true, a jet plane would take off quicker if it were backed up against a wall. If this is not true then, what is the explanation?

The jet engine is moved forward by the same physical factors which cause any other engine to move forward—by reaction to the action of the engine. The following example will help to explain how the reaction principle operates. If a person were in a small rowboat in the middle of a calm lake, how could he make this boat move without using oars? All that would be needed would be a water bucket.

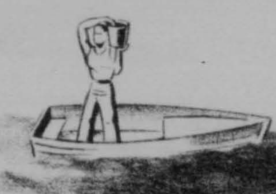
He could dip the bucket in the water and then heave the bucket-full of water over the stern of the boat. The boat would move forward. Why?

If the boat were backed up against a wall,



this would be easy to see. He could push on the wall,—that would be the acting force; in return the wall, by resisting the push, returns the push on him,—that is the reaction force. This "push" on him is transmitted by his feet to the boat, and the boat moves forward. It is easy enough to realize that the boat would move forward if he pushes on a wall. Now to take up the next step.

In the case of the bucket of water, at rest



in his hands it has inertia. By application of Newton's first law a body at rest tends to remain at rest until it is overcome by an unbalanced force. Therefore the bucket of water will remain at rest, in his hands, until he applies force to it. Now this brings up the idea of acceleration. If he pushes gently against this bucket of water, he will just cause it to be poured out easily; and only a small reaction will occur. But if he takes this same bucket of water and hurls it with all his might, he will be putting in a large acting force (he will be accelerating this mass of water rapidly), and the force of reaction will be equal to it. His push against the

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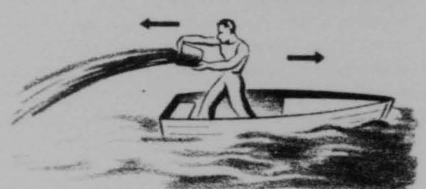
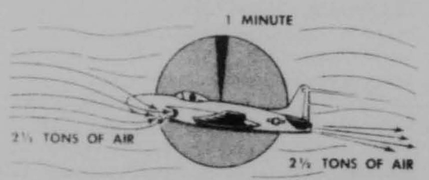
bucket of water will work in the opposite direction, just as though he were pushing against the wall with the same amount of force; and the boat will move.

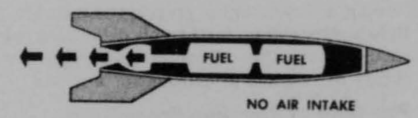
A jet engine does not just throw one bucket of water (mass) overboard. It throws a steady stream of air (mass). To make the boat operate like a jet aircraft the person now becomes the engine; he scoops up water (air—"mass") and hurls it (acceleration of mass) overboard as fast and as forcefully as he can.

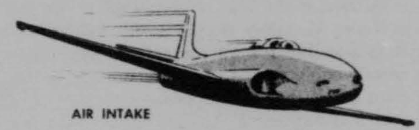


As a result the boat will move along, just as a jet aircraft moves along. It moves because he (the engine) is pushing against (accelerating) a mass of water; and not because the water he is hurling is pushing on the air or on anything else. This is the important part of the whole reaction-propulsion idea.

Now to relate this directly to the jet engine and using the J-33 type as an example. In normal operation this engine scoops up in its air intake scoops, and hurls overboard through its tail-cone, a mass of 2½ tons of air per minute. 2½ tons of air is a tremendous volume; yet this mass is accelerated by this engine every minute as a steady stream. This mass, plus the mass of the fuel consumed in a minute, is the "wall" or "bucket of water" against which the jet engine pushes. The jet engine pushes this air out, and in return it is pushed forward with an equal force.







The difference between the jet engine and the rocket motor is slight. The principle is the same. The jet engine needs air for the mass which it pushes on (accelerates), and to provide the oxygen which it needs to support combustion. The rocket motor carries its own comburent agent (oxygen as an element of gunpowder, or liquid oxygen as a part of its propellant) whether it is a solid-fuel rocket or a liquid-fuel rocket. This difference points out the advantages of each type. The jet engine, because it does not have to rely on mass and oxygen carried with the aircraft, operates more efficiently in the atmosphere; but of course is limited to operation in the atmosphere.

Meanwhile, the rocket motor, because it is self-sufficient can operate most efficiently beyond the atmosphere in a vacuum. When one realizes that the reaction-propulsion principle functions by the push applied to the mass inside the engine, it is easy to understand that a rocket works best in a vacuum. As an example: The air has weight; it is a fluid; it is relatively dense. Therefore, when a jet engine is at sea level, it has to push the mass of air out into that "dense" air. As a result, it has to work harder at sea level than it does at high altitude. In a vacuum there would be no pressure at all outside the tailpipe; so the engine could hurl its mass of

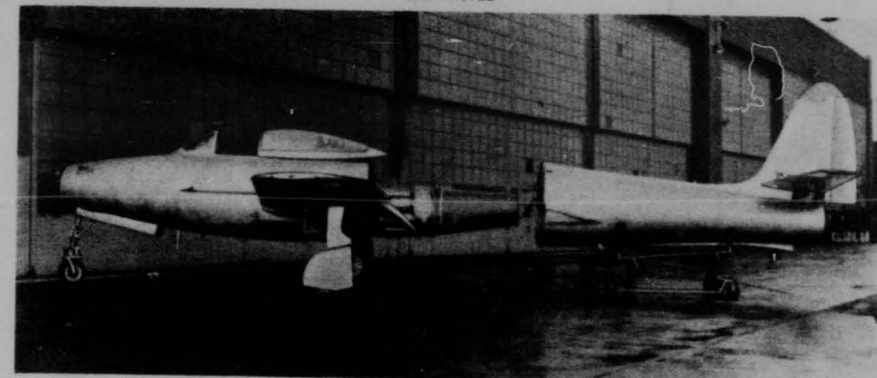


Figure 3-3 Bisected View of F-84 Showing Engine Position

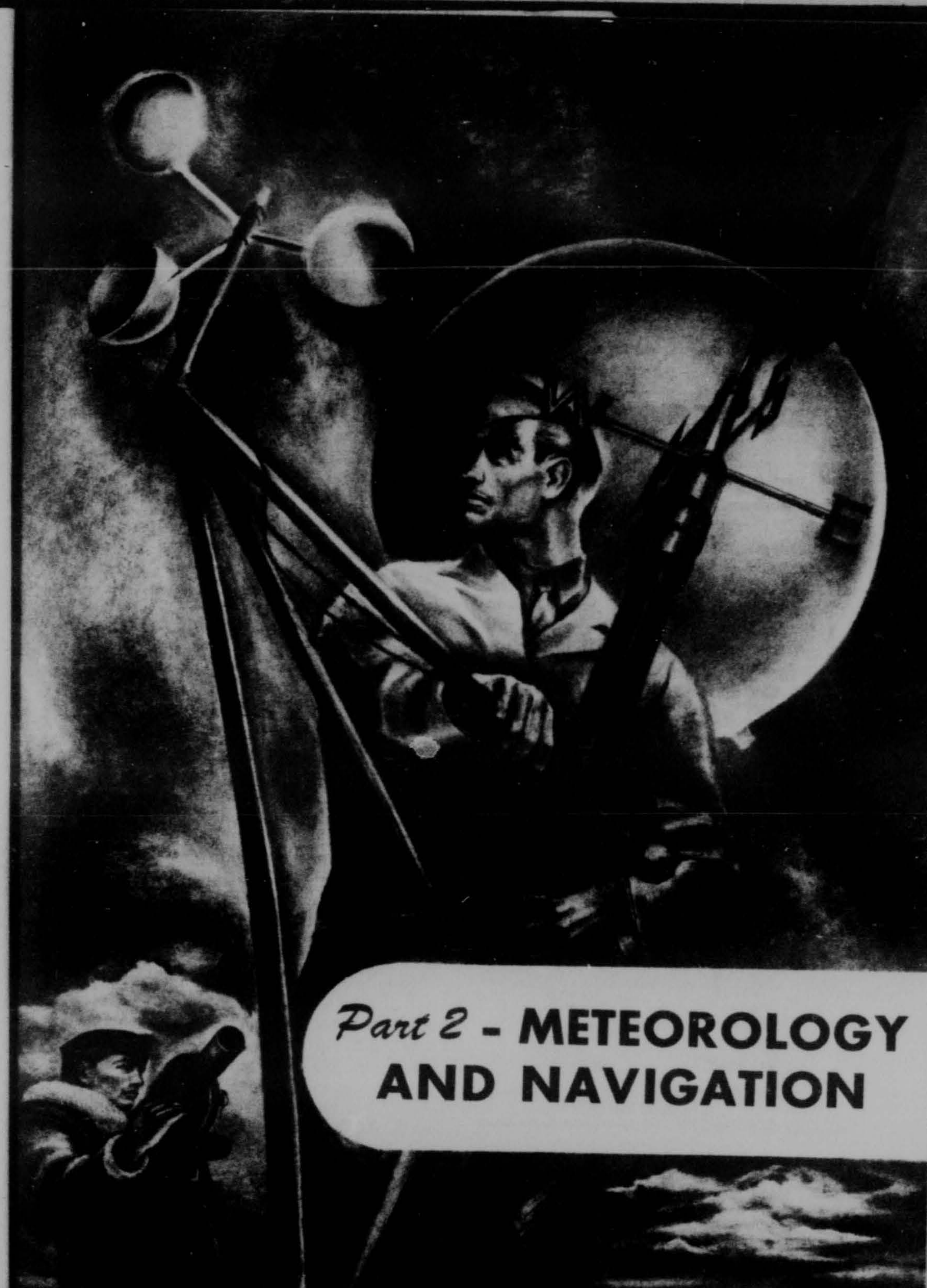
air out easily. Of course the air at high altitude, though it is thin, is not vacuum; but it approaches a vacuum.

When one throws a baseball, one has no difficulty hurling it through the air; but, if one tries to throw a baseball underwater, one finds that the harder one tries to throw the less it seems to move. One would realize that it is most difficult to accelerate a mass in a dense fluid. This is the problem which a jet engine, or rocket motor, encounters at sea level; but the higher the engine goes (other things being equal) the easier it is for the engine to operate.

In thin air, at high altitude, the engine must move faster (travel farther) to scoop up the same volume of air which it did at sea level. And because this thin air creates less drag over the airframe at high altitude, the engine does move the aircraft very fast. The faster the jet engine goes, the more efficient is its operation. Actually the same J-33 jet engine, which develops 4000 pounds of thrust at sea level, develops but 1000 pounds at 35,000 feet; but 1000 pounds at 35,000 feet drives the aircraft faster than 4000 pounds does at sea level.

We have now reached the conclusion in this discussion of "aerodynamics and propulsion." We have only scratched the surface of this very complex subject. In this present period, the power plant has outstripped the airframe; but steps are being taken to close the gap. And this is where the interesting part of the story lies. New airframes with "delta" wings, with swept back wings on which the angle of sweep may be changed in flight, supersonic biplanes, and the use of propellers for supersonic aircraft; supersonic helicopters; and many other designs are being tested.

Furthermore, the whole realm of high-altitude flight creates a new flying world. Temperatures as low as —110 degrees F are encountered, radar refuses to function as predicted, equipment is inoperative because of the cold, and other allied problems create new fields to be explored. This part of the book can not be concluded, it merely comes to an end at a certain page with a limitless story still spread and before it.



Part 2 - METEOROLOGY AND NAVIGATION

CHAPTER 1 - WEATHER

SECTION I - RELATIONSHIP OF WEATHER TO THE AIR FORCE

1. INTRODUCTION

In reading a list of flying regulations prepared in 1918 for one of the first bases established in Alabama, it was noted that the regulations were a bit crude and very brief. One point, however, stood out above the rest—the element of weather. One regulation read, in part: "On cross country flying, remain below the clouds, it may be difficult to find your way through them again." Although it is not necessary to be quite so naive in modern regulations, weather still remains the governing factor in flight planning, whether it is for a cross-country training flight by single airplane or for a major tactical operation involving thousands of bombers and fighters.

In 1934, the importance of meteorology and weather flying was brought home dramatically and tragically to the Army Air Corps. At the order of the President, the Air Corps agreed to fly the mail. But Army pilots were not trained competently to cope with flying through difficult weather, and crashes were all too frequent. The loss of men and airplanes, however, had one salutary effect. Realizing its shortcomings, the Air Corps revamped its training program, and, along with other changes, meteorology and weather flying received major emphasis.

Modern science has made possible flight through almost any type of weather, but restricted visibility and other weather factors still remain the greatest hazards to flying. In addition to improving aircraft, flight instruments, and communication facilities, the progress made in obtaining and disseminating meteorological information has been of utmost importance in making weather flying relatively safe.

Perhaps the greatest evidence of the importance of meteorology to military flying was demonstrated in World War II. The near-disastrous results of the "Battle of the

Figure 1-1 Preparing a Radiosonde System for Its Flight Into the Upper Atmosphere

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Bulge" were due to a large extent to weather which prevented effective use of aircraft by the allies until the last stages of the battle. In an earlier instance the German fleet was able to sneak two battleships through the English Channel under the cover of fog. These are but two examples of the part that weather played in the moves and countermoves of combat.

2. WEATHER INFLUENCES ON PLANNING AND OPERATIONS

Effect of Weather on Base Location and Structure

Consider the weather factor as it affects the choice of an airfield site, the buildings that are going to be placed upon it, and the types of runways that may have to be used.

Location. It is conceded that there are many other factors besides weather conditions that should be considered in the location of an airbase. Unfortunately, however, many airbases have been located without regard to the possible influence of weather. Some of our own airfields, located on the leeward side of smoke-producing cities offer one outstanding example. Their location on the side of the city from which the prevailing winds blow would have reduced substantially the restricting visibilities from which they now suffer. Some of the airfields used by our tactical air forces in Europe were flooded when excessive rains caused nearby streams to overflow their banks.

There is a noticeable difference in the flying weather along the Pacific Coast of British Columbia and Alaska and that prevailing over the interior behind the mountains. The coastal weather is usually wet and cloudy. Weather at inland bases is much cooler in the winter, but also much drier, and on the whole, much more suited for bases from which to conduct aerial operations.

Structure. The weather factor must be considered in determining the types of buildings that are to be erected on an airfield. Some of the hurricanes that have occurred on the Gulf Coast have shown that the builders failed to consider the wind velocities to which some of the hangars would be subjected. Strong winds are not limited to the hurricane belt of the Gulf Coast. In Greenland, about the only places from a topographic standpoint that airbases can be located, on the east and west coasts particularly, are in the fiords. Air sliding down off the Greenland icecap to the sea has been known to blow through the fiords at velocities of more than 120 miles per hour. Winter winds up to 80 miles per hour have been recorded in the Canadian Arctic. Obviously, buildings in the far North must be well insulated to keep out winter temperatures of 50 to 60 degrees below zero. This insulation is necessary from a fuel economy standpoint as well as for personal comfort.

A weather factor entering into the construction of runways is the direction and velocity of the prevailing winds. Soil and temperature considerations also are important. Some clays and volcanic ash swell or "heave" when they get wet. This "heaving" action is much like that which occurs when one cooks rice with water. The whole mass ends up with a volume apparently larger than both volumes combined. A runway laid in "heaving" soil will not be a runway very long. The temperature range of the area in which the runway is to be laid must be taken into account. In the Arctic, summer maximum temperatures often go well up into the 90's, and sometimes reach as high as 100°. In the winter, temperatures may slide down to as low as 50 to 60 below, and sometimes even lower for short periods. This wide annual range in temperature imposes severe demands on the expansion capabilities of a runway, and is one of the problems that must be considered in planning bases for Arctic operations. Much of the ground in the Arctic is tundra. This freezes in the winter but thaws in the summer for the first few feet and remains frozen deeper down. In summer, the ground cannot drain effectively due to the frozen ground below it, so a soft mass results. No effective way of overcoming this difficulty yet has been found. With our present heavy aircraft this presents a difficult problem to overcome.

These factors indicate that the weather is an important factor to be considered in construction of air fields. The best that can be done to overcome the weather factor or properly account for it in planning of air bases is to make a climatic study of the area and

assess the weather factor from that.

Influence of Weather on Offensive Missions

In planning an aerial offensive, the weather factor assumes the highest importance. What type of aerial offense will be conducted? Will it embrace nighttime, or daytime operations, or both? How many of the missions may be required to utilize instrument bombing techniques and how many may be expected to be visual?

Type of Mission. With respect to night operations versus daytime operations, many of the industrial areas of the world lie in areas under the influence of maritime air; that is, air that has had a long trajectory over water. In the absence of frontal activity which produces general cloudiness, this maritime air is likely to react to daytime heating by producing cloudy conditions. These conditions often are accompanied by thunderstorms or showers. As evening approaches, the clouds usually decrease and skies are clear the greater portion of the night. A complaint frequently heard in the European theater was: "Why isn't the weather as good in the daytime when we are running our missions as it is at night?" The same thing occurs in the Gulf Coast area.

Thunderstorms, rain, and snow showers resulting from daytime heating must be taken into account in planning instrument bombing techniques. A thunderstorm or a shower will reflect electromagnetic impulses very well. There is no telling how many thunderstorms, snows, and rain showers were bombed in the last war. It definitely happened in more than one instance. Due to the lower freezing level in the northern latitudes, maritime air will produce showers from clouds with less build-up than is normal in the Gulf Coast area. This is particularly true in the wintertime when snow showers fall from clouds with insignificant build-up. The farther north, the more limitations are forced on flying operations. Advantage must be taken of the best seasons. At all times must every aspect of probable weather conditions be considered in planning day or night flying operations.

Size of Force. What will be the magnitude of the operations? What size mission shall be planned? If the A-bomb is used, it must be delivered to the target if the mission is to be effective; it is of no value in the bomb bay of an airplane. Will three planes be sent out to a single target on the theory that two of them may abort because of weather? Or, will it be necessary to send five or ten? Will an average of one plane out of three or five get through the weather. Suppose that the conventional type of bomb is to be employed. This involves the operation of large forces of bombers. The larger the force, the more weather must be considered in planning, due to the loss of maneuverability which accompanies the increase in numbers. To what extent will the weather over our bases limit the size of the force that can be sent? To what extent will the weather along the route influence the size of the force? All these questions must be answered in some way before a meaningful plan can be evolved. The weather factor may not be the only factor or even the controlling one, but it is a factor that must be taken into account.

Effect of Weather on Defensive Operation

The weather factor is not quite as important in air defense plans as it is in air offense. However, consideration of weather as it affects the enemy's ability to operate may provide a clue to the extent of his operations during certain periods of the year.

If the whereabouts of enemy bases and the types of equipment he is using are known, general assumptions regarding the type of weather conditions that would limit operations out of those bases may be made. A climatic study would show the frequency of those limiting weather conditions by month or season.

Weather would enter into the location of interceptor bases in the same manner previously mentioned in connection with planning bases from which to conduct offensive operations. Interceptor operations in the air defense of the Los Angeles Basin area are more difficult than in the interior. Along the coast, aircraft are likely to encounter fog, low stratus clouds, haze, and frontal weather. Bases should be located in the area of good weather with the mountains between the

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bases and the sea.

It is evident, therefore, that weather should be considered in air defense plans mainly from the standpoint of estimating enemy capabilities and in locating interceptor bases. Again, the climatic study is the only means available for assessing the influence of weather in plans for air defense.

SECTION II - CLOUDS AND SKY CONDITIONS

1. CLOUDS AND WEATHER

One of the things most commonly associated with weather is the presence or absence of clouds. Bad weather is commonly thought of in terms of large, black, clouds and precipitation. A nice day is thought of as one during which there is a clear blue sky with patches of white fluffy clouds floating about. Clouds are like store signs. They tell what may be expected inside. Knowing how to read these signs is invaluable knowledge to the pilot. Clouds should be considered not only in the light of what should be avoided, but also in the light of how they can be used for concealment.

2. SKY CONDITIONS AND CEILING

In referring to cloud cover, meteorologists refer to the "ceiling."

Definitions

"Sky condition" refers to the coverage of the sky by clouds. "Ceiling" may be thought of simply as the height of the base of the clouds, in feet, above the ground, providing the clouds cover more than five-tenths of the sky. A ceiling is said to be unlimited when the cloud cover is five-tenths or less, or the base of the clouds is above 10,000 feet.

Amount of Coverage

When five-tenths or less of the sky is obscured by clouds but more than one-tenth is covered, the sky condition is referred to as **scattered clouds.** If more than five-tenths of the sky is covered but a portion is visible, the sky condition is then referred to as **broken clouds.** Broken clouds constitute a ceiling if more than nine-tenths of the sky is covered. If the sky is completely hidden by clouds, the condition is known as an **overcast.** A pilot flying through or over an overcast, or a broken condition, is said to be flying under instrument conditions because he cannot maintain his bearing or his course by visual reference to the ground.

Ceiling Classifications

In general, ceilings are classified according to the manner in which they are observed or measured, and are reported accordingly. They are correctly reported to the nearest 100 feet.

Measured Ceilings. Measured ceilings are ceilings that are measured accurately by some type of mechanical device or an accurate reference. Some of the methods of measurement are as follows:

Ceilometer. The ceilometer is the most modern instrument developed for measuring ceilings. A modulated beam of light is projected to the base of clouds. Some distance away on a measured base line is an "eye" equipped with a photoelectric cell which scans the beam of light and locates its intersection with the base of clouds. The angle between the horizon and the line between the "eye" and the intersection of light beam and base of clouds is recorded automatically in the weather station. The height of clouds is equal to the length of the baseline multipled by the tangent of the above angle.

Ceiling Light. During the hours of darkness, the height of the base of the clouds may be determined by the use of a light known as the "ceiling light." By observing the point at which the light strikes the overcast through a clinometer (a device very similar to the common transit) some distance away on a measured base line, and applying triangulation, the height of the base of the clouds may be determined accurately.

Radiosonde Balloon. A small radio is attached to a hydrogen-filled balloon and allowed to ascend into the overcast. This radio transmits values of pressure, temperature, and moisture content of the air at regular intervals to a ground recorder. The point at which the radio strikes cloud cover can be determined by analyzing the changes in moisture content.

Balloon Ceilings. The ceiling height may be calculated from the rate of ascent and time of ascent of a hydrogen-filled balloon into the overcast. This method is less accurate than some of the other methods.

Indefinite Ceiling. In many instances the base of the clouds is very indefinite. The bottom may be uneven or very thin and it is difficult to determine just when a balloon enters into the overcast or just where the ceiling light strikes the clouds. This type of ceiling is known as an "indefinite ceiling" and is reported as such.

Aircraft Ceiling. These are determined by requesting a pilot flying over a weather station to report the height of the base of the clouds as read on the aircraft altimeter. The pilot may radio this information of his own volition.

Estimated Ceilings. As the name implies, an estimated ceiling is one that is estimated without the use of mechanical aids by a weather observer on the ground. It is one of the most common methods of determining ceilings. The inaccuracy of this method is quite obvious. However, an experienced observer usually will be correct to within a few hundred feet.

Precipitation Ceiling. A precipitation ceiling is not necessarily the height of the base of the clouds, but is the altitude at which a pilot would not be able to have visual reference to the ground due to the amount of precipitation. This type of ceiling may be determined by any of the above methods, especially pilot reports, the use of balloons, or estimations.

3. CLOUDS

Clouds are the most important single weather element visible to the aviator, and their proper analysis should be the constant goal of all personnel interested in the operation of aircraft.

When a volume of air is cooled, it has a greater mass per unit volume of water vapor. After the saturation point is reached, condensation may occur in either a liquid or solid form, depending upon whether the temperature is above or below the freezing point. Condensation does not occur throughout the entire mass of the humid air, but around small condensation nuclei, chiefly smoke or dust atmosphere. A cloud is composed of a great number of small water droplets, ice crystals, or both, which are separated from each other. The diameter of the water droplets is very small, ranging from 1 to 70 microns, with the most frequent diameter being 12 microns. There are about 50 to 500 of these particles in a cubic centimeter of cloudy air. The rate of fall of these droplets is so small, a few millimeters per second, that the slightest ascending air current is sufficient to hold them aloft. Rain drops, on the

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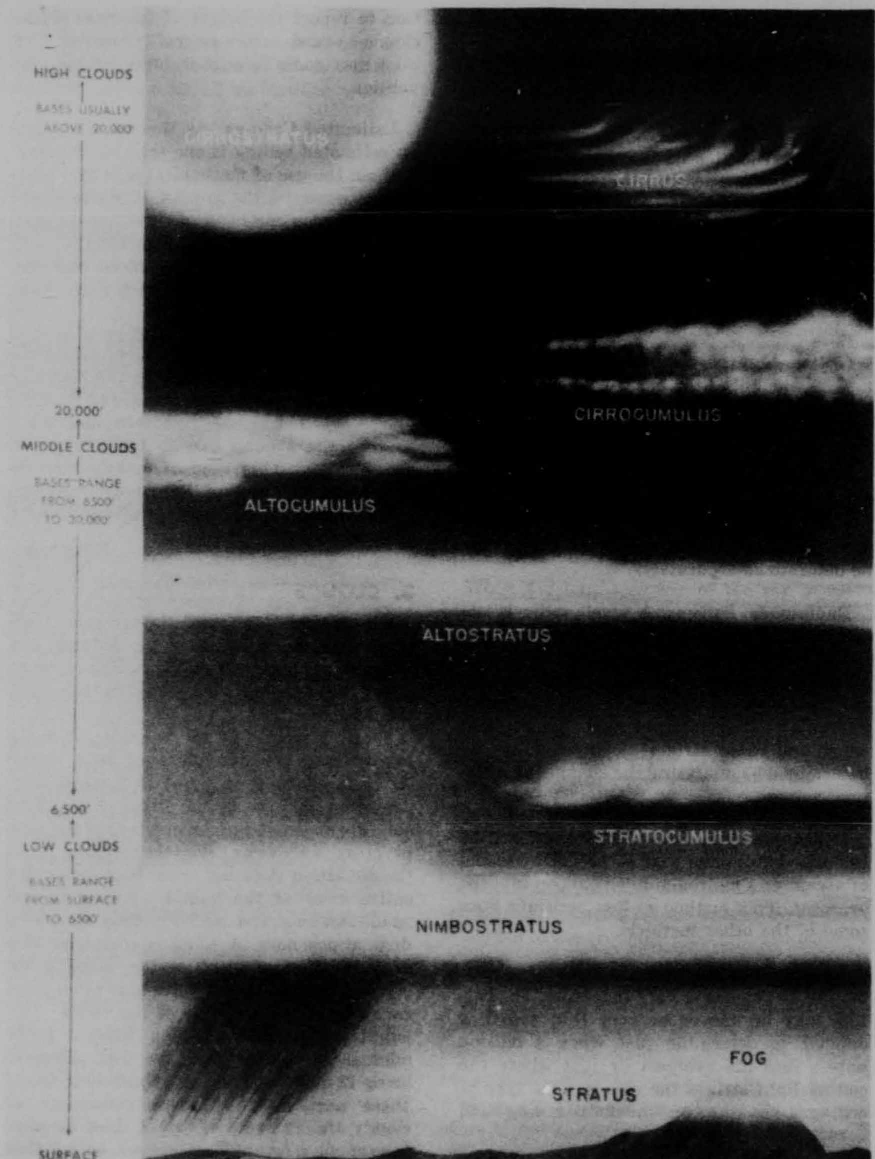

Figure 1-2 International Classification of Clouds

WORLD POLITICAL GEOGRAPHY AND AIR POWER

1. Political geography is defined as the study of the areas and resources of the various states organized as political units, together with the people who live in these areas. Applied Air Power is in a large sense applied political geography since the proper application of air power is based on careful consideration of the facts and principles of political geography with regard to enemy states. The most effective application of air power must take into account such geographic factors as the climate, topography, drainage, natural resources, urban pattern, transportation and communications, industrial facilities, and population distribution of the country under attack, and perhaps of allied and neutral nations as well.

2. The objective of warfare is the destruction of the enemy's capacity and will to fight. Modern mechanized, technical warfare is based on a complex industrial organization and the enemy's war potential can be neutralized most effectively by striking at the heart of the system producing war materials. Air power provides practically the only immediate means of bypassing battle lines and defense lines and reaching these targets, many of which are located far from national boundaries.

3. Proper consideration of geographic factors in the assigning of target priorities can result in neutralizing much of the industrial potential of the enemy. The effect of the destruction of finished products is felt more quickly at the battle-front, but the destruction of raw materials and production facilities is more lasting, even permanent, in effect. A tank arsenal is an obvious target, but much more damage to the enemy would result from destruction of a plant making steel, sulphuric acid, ball-bearings or nitrates.

4. A knowledge of geography will reveal not only an enemy's deficiencies in strategic materials such as tungsten, foodstuffs, ball-bearings or petroleum, but his source of supply and the route of delivery. Attacks can then be directed against transportation lines and port facilities for handling such materials.

5. Damage to transportation systems prevents, at least temporarily, the delivery of supplies to the fronts and raw materials to industry and the movement of troops and reinforcements. Best results can be achieved by attacks on bottle-necks or especially vulnerable points such as cuts, fills, bridges, passes, tunnels and other stretches of single track or service facilities such as round-houses and repair shops. Deductions as to the location and vulnerability of such targets can be made from the topography and drainage pattern of an area and its industrial organization. For example, damage to the New York State Barge Canal would not be of primary significance, while damage to the Soo Canal would seriously cripple the American steel industry.

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6. With the increasing tendency to disperse defense plants and keep their location secret, geographical information is more important, since geography imposes many limitations on location of factories and transportation lines. A knowledge of climate may help determine the best time of year, or even the best time of day, for operations and will aid in the selection of special equipment necessary for successful missions.

7. Increasing recognition of the importance of psychological warfare gives added significance to the distribution of ethnic, religious, racial, cultural and political minorities. Concessions to the problems, attitudes and aspirations of such people may contribute to the effectiveness of air power in destroying the enemy's will to fight.

8. In the use of air power in tactical situations a knowledge of the topography and transportation system is essential in inhibiting the enemy's use of a facility, harrassing his operations or interdicting an area.

9. Political geography provides information in the light of which we can most efficiently seek intelligence for the application of air power and evaluate the significance of information when it is obtained. It provides a frame of reference for drawing sound conclusions regarding strategic and tactical situations. Furthermore, it implements our traditional American policy of training an informed fighting man, one capable of drawing logical conclusions concerning our security problem.

other hand, which are composed of an accumulation of small droplets, are comparatively large and fall with appreciable velocities.

In general, clouds are divided into two main classes according to their form or method of development. Those that form in layers and have horizontal development are known as stratiform clouds. Those that have vertical development are known as cumuliform clouds. So that clouds may be discussed internationally, there is an international cloud classification which is based primarily on height. In brief, this classification is as follows:

High Clouds	20,000—40,000 feet
Middle Clouds	6,500—20,000 feet
Low Clouds	Surface— 6,500 feet
Clouds with vertical development	All Altitudes

Stratiform Clouds

STABLE AIR

(See Figure 1-2.) Stratiform clouds are flat, occur in layers, and usually form in stable air. Stratiform clouds generally cover large areas, and the air within and around them is smooth. They are generally associated with warm air masses or warm fronts, which will be discussed in the following chapter. Stratiform clouds are produced by the cooling of certain strata of the air. Such cooling takes place in one of two ways: radiational cooling by a land surface; and advective cooling, which occurs when the air is lifted over a gentle slope. In either case, the air near the surface, or some strata of the air becomes cooler and therefore heavier than the air aloft. As a result there is little or no vertical circulation. If this cooling is sufficient to lower the temperature of the air to the point of condensation, stratiform clouds will be produced.

Flying Condition Associated with Stratiform Clouds. In stratiform clouds, because of the absence of vertical currents, water drops need overcome only the buoyant effect of air before falling as precipitation. As a result, stratiform clouds yield small-drop, continuous precipitation. There will be little evidence of turbulence in this type of cloud, and other than restriction to visibility, they present no great hazard to flying. At temperatures from 0°C. to —18°C, icing may occur, however, the icing is usually of a not too dangerous type known as "rime ice." (Ice forms on the wings in the form of small pebble-like droplets similar to sleet. It usually is easily removed, and the icing is relatively slow.) In nimbo-stratus clouds when temperatures are between 0° and 90° clear icing usually occurs.

FLYING CONDITIONS GOOD

Types of Stratiform Clouds. Cirrus. (See Figure 1-2.) Cirrus clouds are fibrous and delicate in appearance. They look like white wisps against the blue of the sky. These white wisps appear in a number of forms. Sometimes they appear streaked across the sky and look like mares' tails; at other times they appear as curls or feathery plumes. Cirrus have little thickness and have little significance other than that they may indicate the approach of a warm front if they appear thin at first and then become more compact as they move over. They are very high clouds and are composed of ice crystals.

Cirro-stratus. (See Figure 1-2.) Cirro-stratus appears like a white veil covering all or most of the sky. It forms in a smooth, thin layer and gives the sky a very milky appearance. Cirro-stratus is identified easily by the halo it produces around the sun or the moon. Like cirrus clouds, cirro-stratus is a very high cloud and is composed entirely of ice crystals. Their presence indicates the approach of a warm front.

Cirro-cumulus. (See Figure 1-2.) Cirro-cumulus clouds appear like fleecy flakes or very small white cotton balls. They are very uncommon, appearing only in the presence of cirrus or cirro-stratus. They are high clouds of ice-crystal composition and, like all cirrus type clouds, are found at the level where condensation trails may be formed.

Alto-stratus. (See Figure 1-2.) Alto-stratus appears like a grey or blue-grey, smooth cloud layer from the ground. It is usually thicker and less transparent than the cirro-stratus, which often lowers and merges with alto-stratus as a warm front approaches. The sun and moon shine through alto-stratus weakly as though through a ground glass. The upper surface is wavy or bumpy in appearance. The alto-stratus is a middle cloud that is composed of water droplets. Due to the fact that it is

Figure 1-3 Clouds in Vertical Development

a middle cloud and covers large areas, it is often used tactically for concealment purposes.

Alto-cumulus. (See Figure 1-2.) Alto-cumulus sometimes looks like cirro-cumulus, but the individual cloud balls or flakes are always large, thicker and more gray. The center of the underside of each cloud is dark due to the cloud's thickness. These ball-like masses often appear like a herd of sheep. The visibility within them is poor and the clouds lack continuity. Turbulence and icing, if any, are light to moderate. During the war, fighters often used them for ambush purposes. They are middle clouds.

Nimbo-stratus. (See Figure 1-2.) Nimbo-stratus clouds are thick, dark, ragged clouds, ominous and formless in appearance. Rain, snow, or other precipitation normally is falling from this type of cloud. Even if the rain temporarily stops, this cloud has a ragged, rainy appearance and is still called nimbo-stratus. The sun or moon is not visible through it. Nimbo-stratus is usually at least 6,000 to 8,000 feet thick and often blends into the alto-stratus above. Bases sometimes reach the surface of the ground.

Stratus. (See Figure 1-2.) Stratus is a flat, shapeless, rather uniform layer of cloud appearing dull gray and looking like fog when viewed from below. Stratus-type clouds are often confused with nimbo-stratus but differ mainly in the amount of precipitation that is falling. Stratus never yields more than a slow

drizzle. It is a low cloud whose base may reach nearly to the surface of the earth.

Strato-cumulus. (See Figure 1-2.) Strato-cumulus usually occurs as an extensive and fairly level layer marked by thick rolls and dark, rounded mass of clouds. Strato-cumulus may or may not have large breaks between the rolls and masses. Viewed from above it has a cumuliform appearance but does not have the same vertical development. The thickness varies from 500 to 4,000 feet and turbulence may be light to moderate. Occasionally, light rain, or snow may fall from strato-cumulus clouds.

Cumuliform Clouds

Cumuliform clouds are clouds with vertical development. They occur in unstable air, and the air within them and around them is turbulent. Cumuliform clouds may be a result of the heating of the earth's surface within an air mass, the sharp lifting of air by a cold front, or some orographical effect.

Flying Conditions Associated with Cumuliform Clouds. In cumuliform clouds the water drops must grow to considerable size to overcome the resistance of the vertical air currents before they will fall as precipitation. The vertical currents are not constant, but have a gusty character. As a result, cumuliform clouds yield large-drop, showery precipitation. Because of the vertical currents there is a large amount of turbulence, and when icing occurs it may be of the clear or glaze type. Clear ice, as the name indicates, is a clear form of ice that follows the contour of the wings and is difficult to remove. It is, therefore, considered to be the most dangerous type of ice.

Types of Cumuliform Clouds. There are three general types of clouds with vertical development:

Cumulus. (See Figure 1-3.) Cumulus clouds are dense, detached clouds having a flat uniform base. They are dome-shaped and appear rounded, bulbous, or cauliflower-like. The vertical development is usually between 1,000 and 4,000 feet. With bases at 2,000 to 5,000 feet, cumulus clouds are often termed fair weather clouds.

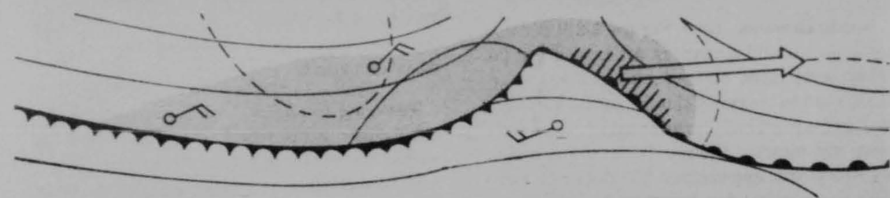
Towering Cumulus. (See Figure 1-3.) Towering cumulus are merely large cumulus with vertical development up to 18,000 feet. Icing may be moderate to severe and is of the clear type. The bases usually run from 2,000 to 5,000 feet. Precipitation does not fall from cumulus clouds, but does fall from well-developed towering cumulus.

Cumulo-nimbus. (See Figure 1-3.) Cumulo-nimbus clouds develop from towering cumulus. They have vertical development up to 30,000 feet or higher. The top is a heavy swelling mass of clouds that usually spreads out into the shape of an anvil. This anvil portion is composed of ice crystals and has a fibrous texture. Cumulo-nimbus are thunderstorm clouds and constitute the most hazardous type of flying weather. Associated with these clouds are violent up and down drafts, heavy rain, or snow, hail, gusty winds at the surface, and thunder and lightning. Thunderstorms have caused many aircraft crashes and should be avoided when possible. These clouds may be found singly, late on a hot summer afternoon, or often in a line along a cold front, or in advance of a cold front as squalls. They also may be formed along a warm front hidden among the warm front system of clouds.

4. VISIBILITY

Visibility is the distance a pilot can see horizontally measured in miles or fractions thereof. When the visibility is more than fifteen miles, it is said to be unlimited. When it is less than three miles, it is generally considered to be a definite hazard and causes instrument flying conditions. The most common restrictions to visibility are fog, precipitation, smoke, clouds, haze and dust.

SECTION III - AIR MASSES AND FRONTS



1. INTRODUCTION

All weather is the result of air masses and their movements. Various types of air do not mix readily. A large mass of warm air will not mix with a large mass of cold air but will have a tendency to overrun the cold air. It is in the boundaries between air masses, known as "fronts," that much of the bad flying weather exists. The study of air masses and fronts is one that is long and difficult. Only the basic principles will be considered in this section.

2. AIR MASSES

An air mass is defined as a large portion of the earth's atmosphere that approximates horizontal homogeniety. It is evident, however, that a mass of air that lies over the Gulf of Mexico for a long period of time will be vastly different from one that has been formed over northern Canada. The air lying over the Gulf will become warm and moist, while that over Canada will become cold and dry. Such regions as those of northern Canada and the Gulf of Mexico which give definite characteristics to an air mass, are known as source regions. Air masses which remain over them for a period of time will develop certain identifying properties and are classified accordingly.

Classification of Air Masses

Air masses are classified according to their source, and characteristics.

Source. Air masses that originate in the arctic fields of snow and ice and the snow covered portions of the continents are known as polar air masses and are symbolized by a large "P." Air masses that originate in the subtropics are known as tropical air masses and are symbolized by a large "T."

An air mass that originates over land is further classified as continental air and has the symbol "c." One that originates over water is known as maritime air and has the symbol "m." Thus an air mass originating over northern Canada would be further classified as continental polar air or "cP," while one originating over the Gulf would be maritime tropical air or "mT" air. See Figure 1-4.

Temperature. An air mass that is warmer than the surface over which it is passing is known as a warm air mass and has as its symbol a small "w." One that is colder than the surface over which it is flowing is a cold air mass symbolized by a small "k." The final classification then of a mass of air originating in northern Canada and flowing over the warmer surface of central United States would be "cPk." The warm, moist air formed over the Gulf, passing over the South Atlantic states, would be "mTw." The cold air mass symbol is shown on a weather map in blue and the warm air mass is indicated in red.

Air masses do not necessarily retain their original classification. A warm air mass moving over a cool surface at night may become a cold air mass moving over the warmer surface on the following day, and the resultant weather will be changed.

Air Mass Weather

Due to the Coriolis force created by the rotation of the earth, all air masses in the northern hemisphere have a general eastward movement. A warm air mass will add a northward component to this movement and a cold air mass originating near the poles will add a southward component. It is this general trend of air mass movements that assists forecasters in predicting future

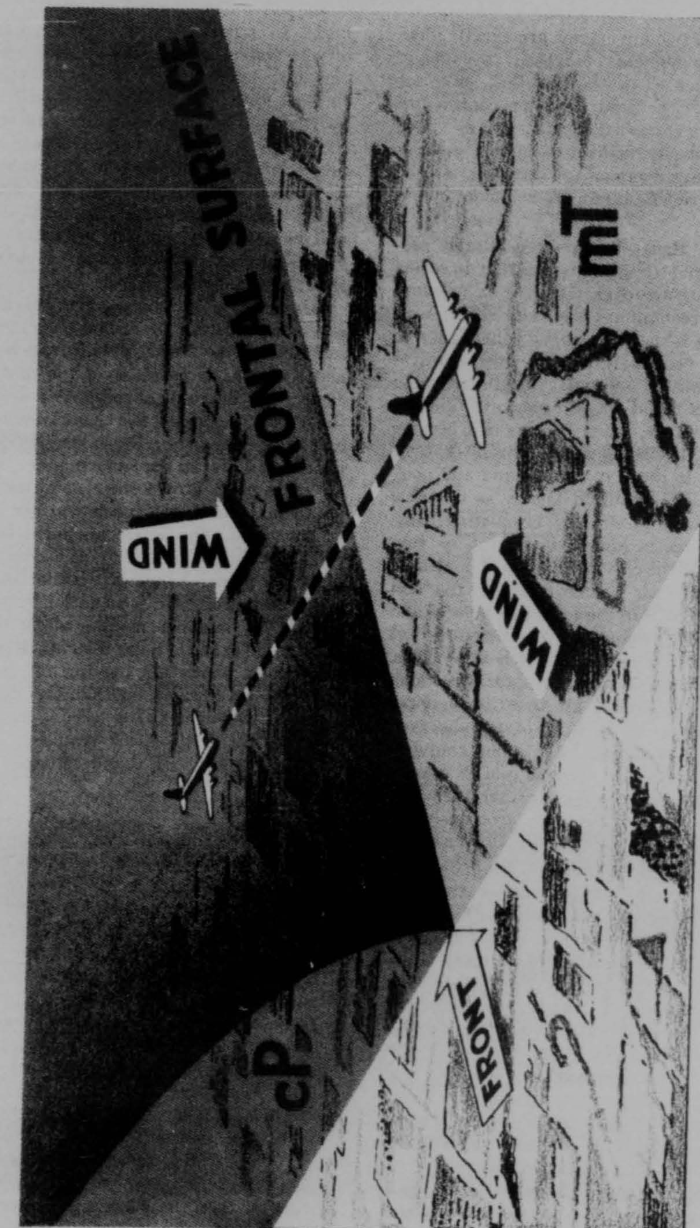


Figure 1-4 Two Air Masses Meeting Along a Front

weather. No two air masses are exactly alike and a large number of types are possible. This is evidenced by the fact that polar air may be of either maritime or continental origin and may be further classified as warm or cold. However, there are certain general characteristics common to warm air masses and there are those that are common to cold air masses.

Cold Air Mass Weather. As stated previously, a cold air mass is one that is cooler than the surface over which it is passing. The most predominant characteristic of such an air mass is that it is unstable in the lower levels. The cooler air passing over a warm surface is heated and will react in the same manner as a liquid placed on a stove. The air near the surface, when heated, will become less dense than the air above it, and will tend to rise. As it rises, it will expand and cool. This creates a condition known as unstable air. The air is constantly circulating, producing up-drafts and down-drafts, or turbulent air. If the cold air mass is of continental origin, the air will be relatively dry and the weather within the area will be cool and clear. If the air mass is of maritime origin it will be relatively humid; if the heating effect is great enough to produce up-drafts which will carry the humid air to great heights, it will condense in the form of cumulus-type clouds or sometimes later even thunderstorms may result. In general, cold air masses are unstable and result in rather turbulent air in the lower levels with good visibility except within cloud formations.

Warm Air Mass Weather. A warm air mass is defined as one that is warmer than the surface over which it is passing. Due to the cooling effect of the surface, the lower layers of air are cooler and therefore more dense than the upper layers. This has a stabilizing effect and warm air masses are, therefore, generally considered to be composed of stable air. Warm air masses that have maritime origin contain large quantities of water, and if the cooling effect of the surface over which it passes is great enough, this moisture will condense in the form of fog or stratiform clouds. This phenomenon explains the presence of fog or low clouds over coastal areas on early mornings following a relatively cool night. In general, warm air masses are relatively stable and humid. Because the air is stable, the elements which restrict visibility, such as dust, smoke, and haze, will remain near the surface and visibility will be poor. If this air is lifted and cooled either by terrain or by overrunning cold air, widespread cloudiness and precipitation will result. In flying through a warm air mass, the air will be relatively smooth, visibility will be poor, and there is always the probability of stratiform clouds and fog.

Air masses do not always retain their same classification. Maritime air which originates over the North Pacific will be lifted and cooled as it passes over the continental divide. Considerable precipitation results on the western slope of the mountains and the air may descend on the other side as dry continental air. In the same manner, a warm air mass moving over the cool waters of the ocean may reach the much warmer surface of the coast. The warm air mass then becomes a cold air mass, and, as a result, there will be a great change of weather in a very short distance. Such a situation is common during the summer months along the east coast of Texas and the Florida Peninsula. The moist warm air moving off the Gulf suddenly becomes cooler than the surface of the land over which it is passing and a very unstable air is produced resulting in large cumulus clouds and thunderstorms.

3. FRONTS

Fronts are defined as a line of discontinuity between two air masses of different temperature and density. There are two main types of fronts, warm fronts and cold fronts. When a warm front and a cold front combine, the result is known as an occlusion or an occluded front. It is rather difficult to visualize a frontal surface. Generally, as previously mentioned, warm air masses originate in the tropics and in the northern hemisphere and move northward. At the same time cold air masses move southward. Sooner or later the two must meet; and, when they do, they do not readily mix, and each air mass remains intact. The surface which separates the two is called a frontal surface. Since the cold air is heavier than the warm air, it permits the

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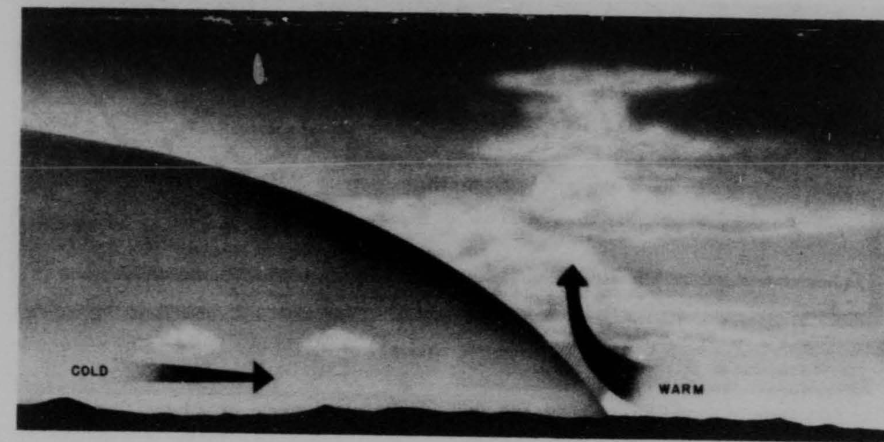

Figure 1-5 Cold Front

warm air to slide up over it, whether or not the cold air is advancing or retreating. Thus, the frontal surface is never vertical, but slopes over the cold air.

Cold Fronts

If the cold air invades the region occupied by the warm air, it will wedge under the warm air, pushing it upward. In this case the frontal surface is known as a cold front. No two cold fronts are exactly alike, but all have certain common characteristics:

As indicated in Figures 1-5 and 1-6, the cold air moving in under the warm air lifts the warm over it. Due to the friction of the earth on the forward edge of the cold front, the forward edge tends to be retarded and the slope of the front is relatively steep. The warm air is lifted rather abruptly over this steep slope causing it to expand and cool very rapidly. This results in an unstable condition,

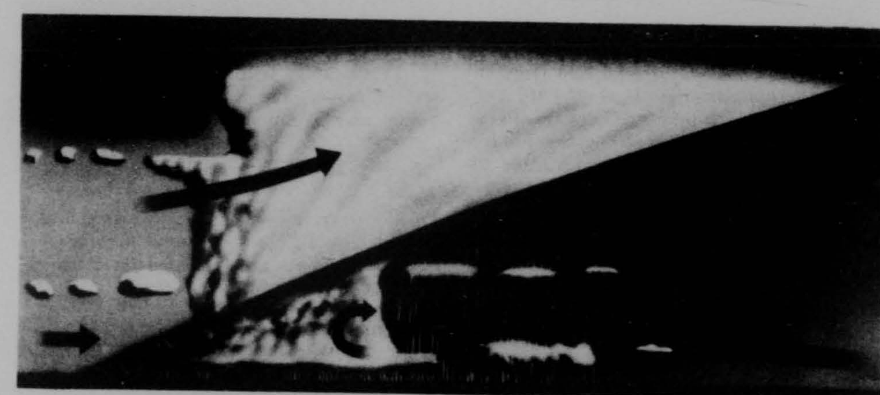

Figure 1-6 Warm Front

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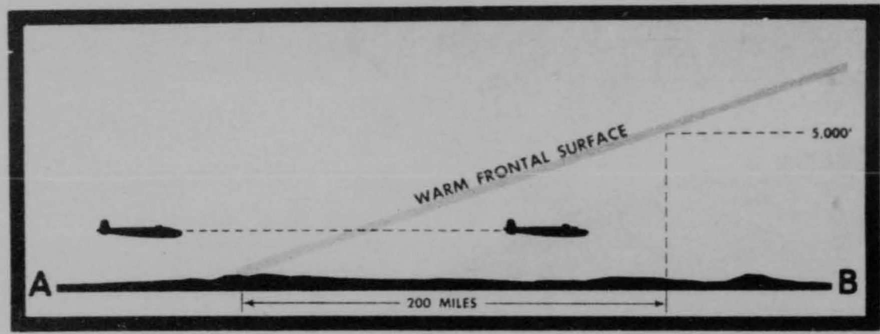

Figure 1-7 Warm Front

the formation of cumuliform clouds, and, in most cases, precipitation. As a general rule, there will be a line of storm clouds along the cold front. In a rapidly-moving cold front this line of instability may extend in advance of the cold front, producing a second line of storm clouds known as a squall line.

Because the slope of the front is steep, the weather bank associated with the front is relatively narrow; it will be found at or immediately following the front, and will clear rather rapidly behind it.

A third identifying feature of the cold front is that as it passes, a sharp decline in temperature will be noted.

The winds behind a cold front will usually shift in a clockwise direction.

The cold front will extend south and west from the area of lowest pressure.

The general movement of a cold front in the northern hemisphere is southward and eastward. Cold fronts are drawn on a weather map in a solid blue line. See Figure 1-4. Generally speaking, it is advisable to avoid flying through a cold front whenever possible. However, if it becomes necessary to do so, the flight path should be perpendicular to the front so as to pass through it in the least amount of time.

Warm Fronts

When warm air is replacing retreating cold air, the frontal surface is known as a "warm front." Some of the identifying characteristics are as follows:

Because the cold air is retreating, the frictional force of the earth's surface on the trailing edge of the cold air retards its progress and causes the frontal surface to be relatively flat. As indicated in Figure 1-7, the slope of the warm front is very gentle. The gentle lifting and cooling of the lower portion of the warm air as it overruns the cold air below generally has a stabilizing effect on the warm air mass in much of the same manner as a warm air mass passing over any cool surface. The resultant weather consists of a wide band of stratiform clouds and precipitation far in advance of the front, with ceilings becoming lower as the front approaches. Warm front weather will often extend as much as 500 miles in advance of the front, but is less severe than cold front weather.

Temperature will increase when a warm front passes, and a slight clockwise windshift may be noted.

The greatest hazards to flying in warm front weather are low ceilings and poor visibilities.

Warm fronts extend southward and eastward from the area of lowest pressure.

Warm fronts are indicated on a map by a solid red line.

Occluded Fronts

It has been stated previously that warm fronts extend south and east from the area of lowest pressure and cold fronts extend

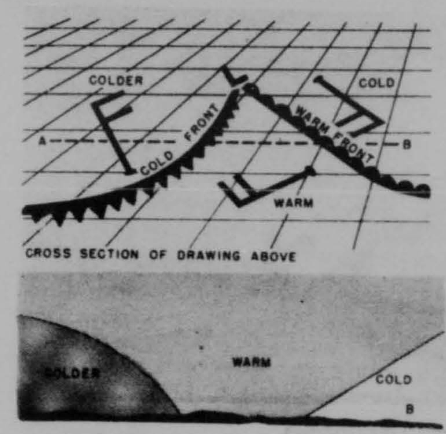

Figure 1-8 Meeting of Warm and Cold Fronts

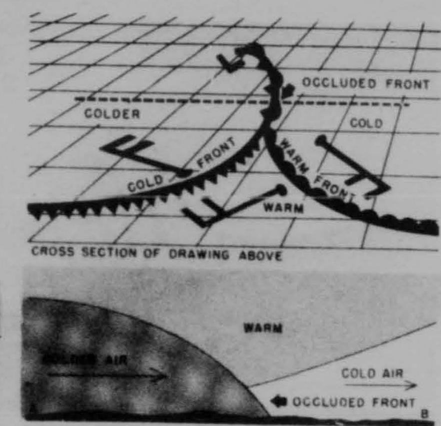

Figure 1-9 Occluded Front

south and west from the area of lowest pressure. This would indicate that there is a point where the warm front and cold front meet. (See Figure 1-8.)

The circulation of air around a low pressure area is cyclonic or counterclockwise. The more rapidly moving cold front tends to catch up with the slow moving warm front, resulting in the formation of a wave.

or an occluded front. (See Figures 1-9 and 1-10.)

Most occlusions are accompanied by extensive cloud cover. (See fiigure 1-10.)

Occlusions have either cumuliform or stratiform types of clouds. Moderate to heavy turbulence may be expected in flying through one. (See Figures 1-10 and 1-11.)

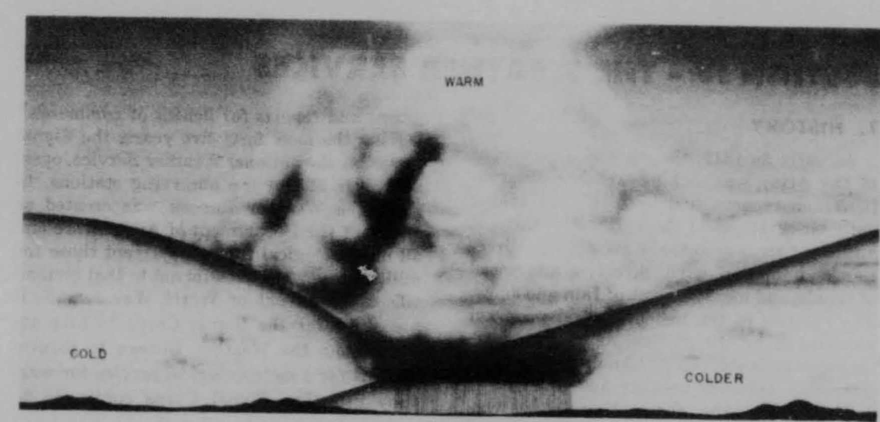

Figure 1-10 Warm-Type Occlusion

Figure 1-11 Cold Front Type Occlusion

Precipitation in the form of rain, snow, or drizzle is common both in advance of and behind the front.

Low ceilings and fog are common in advance of the front.

It is at the point where the cold front first overtakes the warm front that weather will be most severe.

Occlusions are drawn on a weather map in a solid purple line.

Stationary Fronts

There are times when the atmospheric pressure is such that a front apparently will cease to move. Such a front is known as a "stationary front." The warm air in such a front is lifted very gradually and as a result the weather associated with it is not severe. This type of front is indicated on a map by a broken red and blue line.

SECTION IV - THE WEATHER SERVICES

1. HISTORY

As early as 1819, the medical department of the Army was making weather observations and reports, and by 1843 was taking daily observations of the barometer, the wet and dry thermometer, sky conditions, direction and force of wind, direction and speed of clouds, and measurement of rain and snow. The purpose of the meteorological program undertaken by the medical department was to promote better understanding of the relationship between weather and disease.

The first weather forecasting service was created in 1870 and assigned to the Signal Corps of the Army as "the division of telegrams and reports for benefit of commerce." During the next forty-five years, the Signal Corps, as the national Weather Service, operated over 225 of the observing stations. In 1890, the Weather Bureau was created as a part of the Department of Agriculture and all meteorological functions except those for military use were transferred to that civilian office. The advent of World War I made it necessary for the Signal Corps to take experts from the Weather Bureau to form a nucleus for a meteorological service for wartime use. The Signal Corps continued to operate this activity after World War I and provided this service for the Air Corps which

had become by far the largest user of the Signal Corps weather service. On 1 July 1937 the War Department General Staff transferred the weather service from the Signal Corps to the Air Corps.

Air Corps Control

With this transfer, the Air Corps became responsible for providing such weather services as it might need and for furnishing weather forecasts to army headquarters at division levels and higher. All other weather needs for the Army were the responsibility of the arms and services concerned.

The responsibility for the development, procurement, stowage, and issue of meteorological equipment remained with the chief signal officer. He was also made responsible for providing teletype machines and any other communications equipment which might be required for various weather stations.

With the entry of the United States into the war in 1941, the problem of providing an adequate weather service to the various users exceeded any previous estimates. Few weather observations were available to our forecasters for air operations in Africa, South America, Alaska, and the Pacific Islands. It became necessary for the AAF to establish its own weather service in those areas.

By the spring of 1942, the Army Air Force Weather Service had grown to be a world-wide organization. It published information for flight training, air transport, strategic and tactical air operations, and general military planning. It continued to grow throughout the war, reaching a peak strength of nearly 19,000 persons manning approximately 900 weather stations, more than two-thirds of which were in 58 foreign countries.

Extension of Service to Non-Air Corps Troops

In the fall of 1942, the Army Air Force Weather Service extended its services to Army Ground and Service Forces, neither of which was equipped to furnish extensive weather information for itself.

In May 1945, Army Regulation 95-150 was revised to make the Commanding General, AAF, responsible for furnishing weather in-

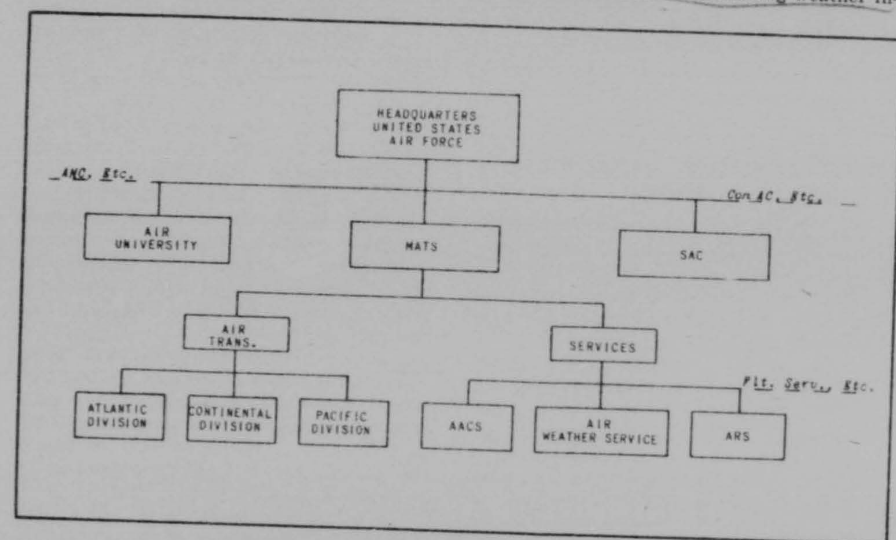

Figure 1-12 Military Air Transport Service

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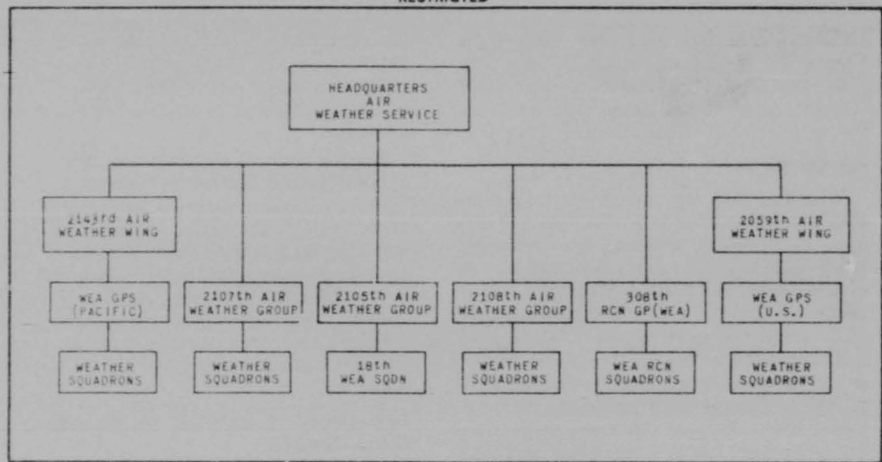

Figure 1-13 Headquarters Air Weather Service

formation to all components of the Army except those which might be specifically exempted by the War Department. Some of the arms and services specifically exempt are the Chemical Corps, the Field Artillery, the Coast Artillery, and the Anti-Aircraft Artillery. This responsibility for provisions of the military weather service still rests with the Air Weather Service in spite of the acquisition of autonomy by the United States Air Force in September of 1947.

2. ORGANIZATION OF THE AIR WEATHER SERVICE

The Air Weather Service now occupies the position in the United States Air Force structure as shown in Figure 1-12.

Figure 1-13 shows the internal organization of the Air Weather Service. It should be noted that below headquarters, Air Weather Service, a vertical command structure extends through wings, groups and squadrons to the lowest element, the weather detachment. In addition to these weather units, which provide weather observation and service essentially confined to land masses, there exist units within the Air Weather Service whose mission includes the provision of "very long range" aerial weather reconnaissance over the otherwise inaccessible areas of the oceans and ice caps.

Primary Functions

The primary functions of the Air Weather Service are to make observations of the weather, to report these observations, to prepare weather forecasts for flights of military aircraft and for all other military operations as requested, as well as to prepare climatic studies of any or all parts of the world as requested. In the United States, this service normally is performed at fixed installations at operating Air Force bases. In a theater of operations, this fixed weather service is likely to be supplemented by mobile weather stations which will move with changing tactical situations to provide weather service as required by Air Force and Army operations, and air transportable weather stations which will be flown into forward air locations.

Figure 1-14 shows the geographical boundaries of the units of the Air Weather Service. If a more thorough study of the organization responsibilities and procedures of the Air Weather Service is desired, the following regulations are listed for reference:

Army Regulation 95-150.
Air Force Regulation 20-44.
Air Force Regulation 20-58.
The 105 series of Air Force Regulations.

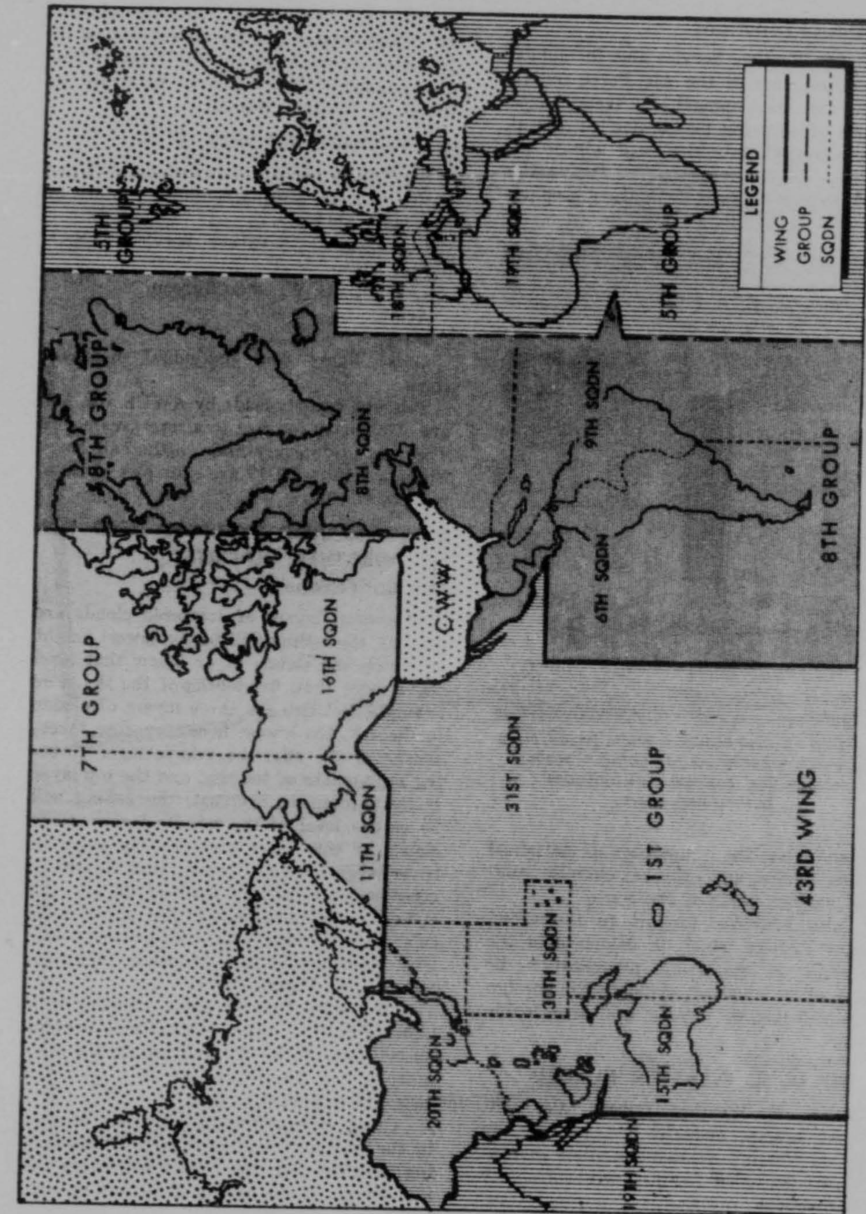

Figure 1-14 Geographical Boundaries of the Units of the Air Weather Service

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Additional Functions

The Air Weather Service also formulates the requirements of the Air Force for research and development in instrumental methods of securing meteorological and allied geophysical data that will add to the knowledge of the workings of the earth's atmosphere upon which military applications must be based.

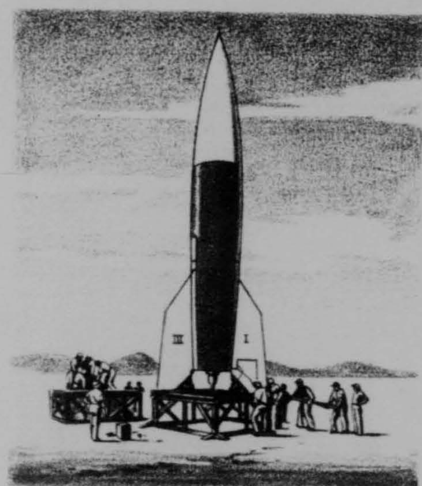


Figure 1-15 Rocket Firing at White Sands, N. M. Rockets are being used to obtain weather information from extreme altitudes in the atmosphere.

It supervises the compilation of statistical weather studies and prepares climatic studies of various parts of the world.

It also provides support to the Cloud Physics Project which is determining the feasibility of procuring precipitation by means of inoculating clouds with foreign substances such as "dry ice" and silver iodide crystals.

3. THE U. S. WEATHER BUREAU

The U. S. Weather Bureau, the civil weather agency, must by law, provide the National Weather Service and other government meteorological facilities with such basic meteorological information normally required in their operations. The meteorological facilities operated and the meteorological information provided by the Air Weather Service augments that which is furnished by the U. S. Weather Bureau.

4. WEATHER REPORTS

Reports are made in the continental United States, Alaska, and surrounding waters by five main agencies.

(AWUS) Air Weather Service (USAF Bases).
(AW) U. S. Weather Bureau.
Army.
Navy.
Coast Guard and individual merchant ships.

Teletype reports made by AWUS and AW are of primary interest to aircrew members. They are made every hour on the half hour. Figures 1-16 and 1-17 are examples of these reports.

5. CODES AND SYMBOLS USED ON WEATHER REPORTS

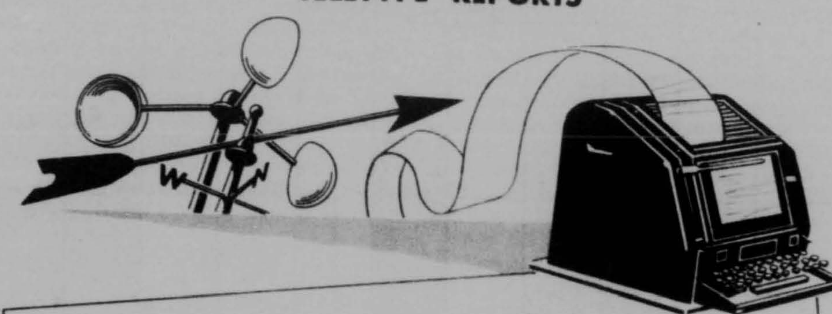
Sky Conditions

If several layers of scattered clouds are present, the ceiling will be the lowest height at which the clouds at or below that level cover more than five-tenths of the sky. For example, if there are three layers of clouds in the sky, the lowest layer covering three-tenths of the sky, the middle layer covering four-tenths of the sky, and the top layer being a complete overcast, the ceiling will be at the level of the middle layer as the clouds of this layer and the one below it cover seven-tenths of the sky. Had the middle layer covered only one-tenth of the sky, the ceiling would have been at the upper overcast layer, as the total cloudiness at any level below would have been less than five-tenths. (See Figure 1-18.)

If fog, dust, blowing snow, blowing dust, blowing sand, or other obstructions prevent observation of the sky and reduce the visibility to less than one-fifth of a mile, the ceiling is reported as zero.

Ceiling is reported in hundreds of feet in the teletype weather report. If the ceiling is 8,500 feet, the report will carry the number 85. If the ceiling is 50 feet or less,

TELETYPE REPORTS



```
AWUS 9891-3 161430Z
WRI 015 M/25/10→↘14/M/ ///9/
RME 40Ф15+ 207/17/3→4/011/RAREP PPINR/35940 35913 99940
BGR Ф35Ф25 095/20/10↘18/980/180Ф RAREP PPPINR/ ///9/
MHT Ф25 152/21/7↘19/995/FEW FC OVHD/ ///9/
BED 015 152/22/-8↓20/996/99980
CEE 015 180/23/7↓↘16+/003/G27/99990 99990
SWF WOX1/2F 149/22/21↓↙19-/995/00004 QIOEN
                                          0930
```

Figure 1-16 Air Weather Service Teletype Report

```
AW 3 160930E
LGA 012 217/25/2→↘20/016/FEW CU
IDL 09 210/27/8↘16/014/FEW FC
FBT 015+ 214/26/7→15/015/FEW CU QUWEN
EWR 015+ 213/27/7↘17/014/FEW CU
BDX 50Ф15+ →↘18
                                          0930
```

Figure 1-17 U. S. Weather Bureau Teletype Report (C.A.A. Circuit.)

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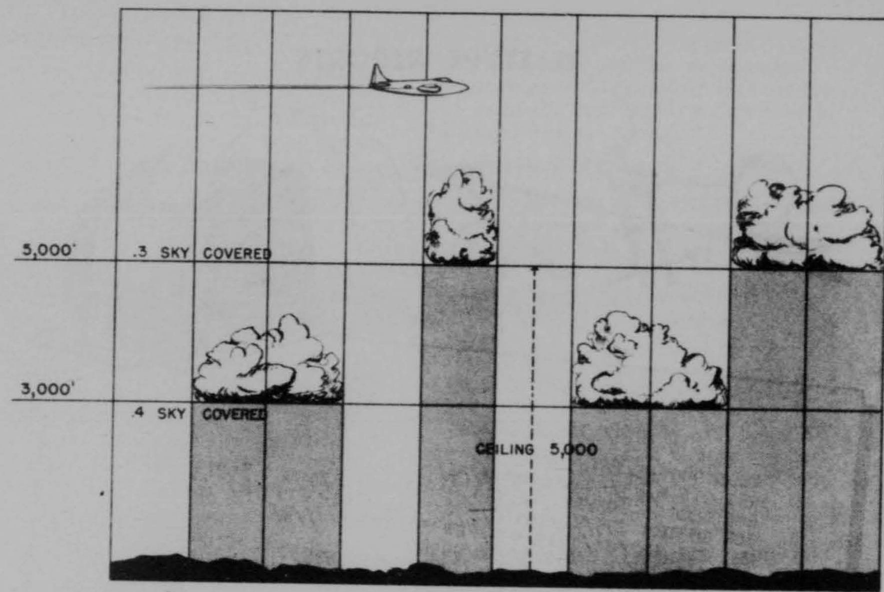

Figure 1-18 Definition of Ceiling Cover

it will be reported as zero and the figure "0" sent on the report. If the height is estimated rather than measured, the letter "E" precedes the elevation. For example, if the ceiling is estimated at 600 feet, the report will be "E6." If the ceiling is unlimited, this element of the report is omitted.

Report of Cloudiness

This consists of two phases, the first dealing with the types of sky conditions; the second, with the height of the cover above the surface of the earth.

Types of Sky Conditions

In making observations and reports the following symbols and words are used to describe the types of sky:

○ Clear; no clouds or less than one-tenth of sky covered by clouds.

⦶ Scattered; one-tenth to five-tenths, inclusive, of sky covered by clouds.

⦷ Broken; more than five-tenths but not more than nine-tenths of sky covered by clouds.

⊕ Overcast; more than nine-tenths of sky covered by clouds.

These observations always are taken at a point from which the entire sky may be viewed, and then the number of tenths of sky covered by the clouds is reported in one of the above terms as based on the entire dome of the sky.

Complete Cloud Report

With the above symbols, two separate layers of clouds may be reported in this section of the report If there is a layer of scattered clouds below the ceiling, the height of that layer will be indicated before the "scattered" symbol in hundreds of feet except when there are two layers of scattered clouds, in which case only the height of the lower layer will be shown. The following examples will illustrate the methods of reporting various types of cloud decks:

30 ⦷ ⦷ reports a 3,000-foot ceiling with a higher layer of broken clouds. 30 indicates that the ceiling is the base of the lower layer

of broken clouds. The word "broken" means that the layer covers more than five-tenths of the sky. The upper layer of broken clouds is at a height somewhere above 3,000 feet.

30 ⊕ ⦷ reports a 3,000-foot ceiling and lower broken clouds, with a higher overcast deck. The overcast layer is above 3,000 feet and the broken layer which determines the ceiling is at 3,000 feet.

30 ⊕ 15 ⦶ reports a 3,000-foot ceiling, overcast, and with lower scattered clouds at 1,500 feet. The overcast layer is at 3,000 feet.

Visibility

Visibility is the mean greatest distance toward the horizon that prominent objects such as mountains, buildings, towers, etc., can be seen and identified by the normal eye, unaided by optical devices; this identification must be possible over a range of more than half the horizon.

Visibility is measured by visual observation, noting the distance at which objects blend into their surroundings. Each observation station has on hand a table of checking points showing the distances of objects surrounding the station. At night, unfocused lights are observed as well as prominent objects against the sky.

Visibility is reported directly in miles and fraction of miles. A fluctuating visibility is indicated by entering the letter V immediately after the report. These examples illustrate the reporting of visibility.

5 indicates a 5-mile visibility.

1¼ indicates a 1¼-mile visibility.

½ V indicates a ½-mile visibility, fluctuating about this value.

X ½ F indicates obscured sky, visibility ½-mile with fog.

6. SPECIAL WEATHER CONDITIONS

This group includes reports of all thunderstorms, squalls, precipitation and restrictions to visibility. Descriptions of each condition and the codes for reporting are given below.

Thunderstorm (reported T). A thunderstorm is reported whenever thunder can be heard. If the storm is especially severe, with wind speeds of over forty miles an hour and incessant loud thunder, the storm is classified as heavy (reported T+).

Rain is a fall of liquid drops of water having a greater diameter than 1/50 inch. Rain may be classified as light, moderate, or heavy (reported R-, R, R+ respectively), depending upon the rate of accumulation of water in inches or fractions of inches in a given time.

Freezing Rain (reported ZR-, ZR, ZR+). Freezing rain is rain which freezes instantly upon striking objects in the open. It is classified in the same manner as rain.

Drizzle (reported as L-, L, L+). Drizzle is a fall of very fine drops of liquid water. These drops seem to float in the air. Their diameter is less than 1/50th inch and fall slower than ten feet per second. Drizzle is classified as light, moderate, or heavy by the degree to which it limits the visibility and not by the rate of accumulation of water on the ground.

Freezing Drizzle (reported ZL-, ZL, ZL+). Drizzle which freezes instantly upon impact with objects in the open is a freezing drizzle. It is classified in the same manner as drizzle.

Snow (reported S-, S, S+). Snow is a fall of white or translucent ice crystals in branched hexagonal shapes. Snow is classified as light, moderate, or heavy, by the degree to which it alone limits the visibility while falling.

Sleet (reported E-, E, E+). Sleet is a fall of transparent, globular grains of ice ranging from 1/25 to 4/25 inch in diameter. It is formed by the freezing of rain drops before they reach the ground. Sleet is classified as light, moderate, or heavy, depending upon the rate of accumulation on the ground.

Hail (reported A-, A, A+). Hail is the fall of ice balls, or stones, with diameters ranging from 1/5 inch to 2 inches or more. They may be either quite transparent or composed of alternate layers of clear and opaque ice. Hail occurs almost exclusively in violent and prolonged thunderstorms. It is classified as light, moderate, or heavy, depending upon the rate of its accumulation on the ground.

Snow Pellets (reported SP-, SP, SP+). Snow pellets are white opaque grains having a snowlike structure. They are usually crisp

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and easily compressed. They rebound and often burst when striking hard ground. Snow pellets fall almost exclusively in showers.

Small Hail (reported AP-, AP, AP+). Small hail is a fall of semi-transparent grains of frozen water, usually with a soft center and a thin, wet layer of ice around the outside, which gives a glazed appearance. It is classified in the same manner as hail.

Showers (reported RW-, RW, RW+), snow reported (SW-, SW, SW+). Showers of either rain or snow occur when the precipitation is of a highly variable character, alternately starting and stopping within 15 minute intervals. They are classified in the same manner as rain or snow, respectively.

Dry Haze (reported "H"). Haze is a suspension in the air of extremely fine particles of dust or other particles which may reduce the visibility quite appreciably. It gives a characteristically dirty appearance to objects at a distance.

Fog (reported "F"). Fog is a suspension in the air of water particles condensed from the vapor state. It is classified in intensity by the degree to which it limits visibility.

Ice Fog (reported "IF"). Ice fog occurs when the particles are ice instead of liquid water.

Ground Fog (reported "GF"). Ground fog occurs only in a shallow layer, so that the sky is visible from the ground. It is reported in the same way as fog.

Smoke is reported as "K" when it reduces visibility.

Dust is reported as "D" when it is distributed in the atmosphere.

Blowing Dust (reported "HD"). When dust is picked up from the surface and blown about in clouds or sheets at low levels above 6 feet, it is reported in the same way as dust.

Blowing Sand (reported "BN"). When sand is picked up locally by the wind and blown about in thick concentrations, it is classified in the same way as dust.

Blowing Snow (reported "BS"). When the snow is not actually falling but is picked up from the surface and blown about in clouds or sheets six feet or more above the surface, and reduces visibility, it is reported as blowing snow. It is classified in the same manner as snow.

7. PROPERTIES OF AIR

General

Air properties may be easily identified in the report by three groups of figures separated by slant marks such as 091/53/45. The first of these is the barometric pressure at sea level in millibars, the second is the temperature of the air, and the third is the dew point.

Barometric Pressure

Pressure may be defined as force exerted on a unit area of surface by a fluid under compression. At sea level, the atmosphere exerts a pressure of about fifteen pounds per square inch. The atmosphere may be thought of as a sea of air with the land and ocean surfaces at its bottom. In the same way that a sea of water exerts an increasing pressure with depth, the pressure exerted by the atmosphere is greater at low elevations than in the upper atmosphere. The pressure of the atmosphere is a result of the weight of the air above that point. With increasing elevation, the weight of atmosphere above a specified point will decrease, and, therefore, the pressure in the atmosphere consistently decreases with increasing height.

The pressure exerted by the atmosphere at sea level does not remain constant. It has been found that variations of as much as 4 per cent above the average and 5 per cent below occasionally will be found. Certain characteristics of barometric pressure have been found to accompany special types of weather phenomena. For this reason, weather forecasters require a knowledge of the pressures that exist over large areas on the map. Barometric pressure is included in practically every type of weather report sent out.

To facilitate their calculations, weather men for several years have used a unit called the "millibar" instead of inches of mercury to indicate atmospheric pressure. Normal atmospheric pressure at sea level is 29.92 inches of mercury, or 1,013.2 millibars. This pressure is given in units and tenths of a millibar, but in reports, only the last three digits of the complete pressure number are sent. For example, a pressure of 1,008.8

millibars would be reported 088. There will be no confusion as to whether the pressure is above or below 1,000 if one remembers that the pressure practically never drops below 950 or rises above 1,050 millibars. A report of 751 could not mean a pressure of 1,075.1 (this would be an improbable high value) but would indicate pressure of 975.1 millibars.

Temperature

Temperature of the surface air is measured by means of an ordinary thermometer kept in the shade. Temperature reports are made directly in degrees Fahrenheit in English-speaking countries, elsewhere in degrees centigrade.

Dew Point

Dew point is an indication of the amount of water vapor in the air. It is defined as that temperature to which the atmosphere must be cooled before water vapor will condense from the air. The dew point is a very important factor in predicting the formation of fog, clouds, and precipitation, as all of these form by condensation of water from the air.

Complete Report of Properties of Air

The following examples illustrate the decoding of this group:

REPORT	PRESSURE
891/44/44	989.1 mb.
091/95/76	1,009.1 mb.
452/-20/-35	1,045.2 mb.

TEMPERATURE	DEW POINT
44°F	44°F
95°F	76°F
-20°F	-35°F

8. MISCELLANEOUS DATA

Winds

Wind may be defined as air moving horizontally across the earth's surface. Winds are found throughout the atmosphere, both at the surface and at upper levels. Reports of winds include an indication of both direction and speed of the air movement.

The direction of a wind is that from which it is blowing. For instance, air movement from the northeast toward the southwest would be a northeast wind. Sixteen points of the compass may be used—north, north-northeast, northeast, east-northeast, east, etc. Airway teletype reports indicate wind direction by means of small arrows which may be thought of as flying with the wind. Only eight arrow symbols are found on teletype machines, so it is necessary to use two arrows to indicate intermediate directions. The following examples illustrate the method of reporting wind direction:

WIND	REPORT
North	↓
North-Northeast (Combination)	↓↙
Northeast	↙
East-Northeast (Combination)	←↙
East	←

Wind speed is measured and reported by airway weather stations in knots. Another system of reporting wind speeds, the Beaufort scale (see Section V), is used by Weather Bureau stations in the 6-hourly reports used for forecasting purposes. The wind speed in knots is entered directly after the wind direction arrow, or arrows in the airway teletype report. If the wind is of a gusty character, it may be indicated by the addition of a plus or minus sign immediately after the wind speed. If the peak speed of these gusts is **twenty-five miles per hour (twenty-two knots)** or greater, the gusts are said to be "strong" and are indicated by a plus sign; if the peak speed is from nineteen to **twenty-four miles per hour**, they are said to be "fresh" and are indicated by a minus sign. The absence of a plus or minus sign indicates the wind is "steady." If the air is calm, the letter "C" is sent.

Wind Shifts. If there has been a pronounced shift in the wind direction which may have special significance, it is reported immediately following the other wind data. This report consists of a wind arrow (to sixteen points of the compass) showing the former direction and the time that the shift occurred. Intensity of the shift may be indicated by the addition of a plus or minus sign, minus indicating a mild shift, no sign a moderate shift, and a plus sign a severe shift.

Complete Wind Data. The following examples illustrate the decoding of wind data in the teletype report:

REPORT	*WIND DATA*
↑ 5	South wind, 5 miles per hour.
↓↙ 25+	North-northeast wind, 25 miles per hr. strong gusts.
↘45+ ↑ 1634C+	Northwest wind, 45 miles per hour, strong gusts, wind shifted severely from the south at 4:34 PM Central Standard Time.
C	No wind (calm)

Altimeter Setting.

The altimeter on an airplane is a sensitive aneroid barometer, or pressure measuring instrument. Its principle of action depends upon the decrease of pressure with elevation. Where the pressure is high, as at sea level, the altimeter reads low elevation; and at high elevations where the pressure is low, the altimeter indicates high altitude. Such an instrument will be in error every time the temperature or barometric pressure changes. Modern altimeters are designed to be set by hand to compensate for errors caused by variations in local barometric pressure. The setting number for correction of a station, called the "altimeter setting," is given in the teletype report immediately following the wind data. When the altimeter is set by this number, it will show the correct elevation above sea level when landing at the field. The setting applies only to that field from which the report was sent. The latest correct altimeter setting should be obtained for each field at which it is desired to land. The setting number is in inches of mercury and averages about 29.92 As with barometric pressure, only the last three digits of the complete number are sent, the decimal point being left out. The following examples illustrate how to decode altimeter setting reports:

REPORT	SETTING
990	29.90 inches of mercury
895	28.95 inches of mercury
045	30.45 inches of mercury

Additional Remarks

Often there is some special weather information which the weather observer wishes to send in the report in addition to that provided for in the regular code. In this case, remarks are made at the end of the report in standard abbreviations and symbols. A few of the most important common abbreviations are listed below:

ALT	Altitude
ARV	Arrive
BINOVC	Break in overcast
BRK	Break
BRONO	Broadcast not operating
BROOK	Broadcast operating normally
CHG	Change
CIG	Ceiling
CLD	Cloud
CLR	Clear
CU	Cumulus (cloud)
DRZL	Drizzle
ETA	Estimated time arrival
FANOT	Fan-type marker not operative
FCST	Forecast
GNDFG	Ground fog
HZY	Hazy
ICG	Icing
IFR	Instrument flight rule
IOVC	In overcast
IPV	Improve
LTNG	Lightning
MDT	Moderate
MSL	Mean sea level
MSTK	Mistake
NOOPV	Not operative
OBSC	Obscure
OTP	On top
OVC	Overcast
OVR	Over
PCPN	Precipitation
PIBAL	Pilot balloon sequence reports (upper winds)

PPINR	No personnel to operate radar set
RAGOK	Radio range operating normally
RAOBS	Radio meteorological soundings
RANOT	Radio range reported as unreliable
RGD	Ragged
RNWY	Runway
RTE	Route
SCTD	Scattered
SNW	Snow
SQAL	Squall
STM	Storm
STN	Station
THD	Thunderhead
THDR	Thunder
THK	Thick
THN	Thin
TLTP	Teletype
TMP	Temperature
TOVC	Top of overcast
TSTM	Thunderstorm
TURBT	Turbulent
UNSTDY	Unsteady
VFR	Visual flight rule
VSB	Visible
VSBY	Visibility
WND	Wind
WB	Weather Bureau
XLNT	Excellent
XTSV	Extensive
ZONOT	Station location marker, ultra high frequency not operating

The above short list includes many of those abbreviations commonly found in weather reports. Many others are used, but they are usually more obvious and can be translated at sight. The following examples illustrate the use of abbreviations in weather remarks:

"PIREPS ICG 15-75 N FW 55-80 MSL": Pilot reports icing 15 to 75 miles north of Fort Wayne at 5,500 to 8,000 feet above mean sea level.

9. TERMINAL FORECAST CODE GROUP

This group of symbols is placed at the end of each AWUS sequence and indicates the forecast for a period of twelve hours from the time of the sequence.

See below the solved forecast for RME Rome AFB.

10. DECODING OF COMPLETE REPORTS

Solved Examples

The following teletype reports have been decoded as examples:

(1) RME 40 ⦶ 15 + 207/17/3→4/011/- RAREP PPINR/35940 35913 99940
Rome A.F.B. 4000′ scattered clouds, visibility over **15 miles,** barometric pressure in millibars 1020.7, temperature 17°F., dew point 3°F, wind west, 4 knots, altimeter setting 30.11 in. of mercury, no personnel to operate radar set. 4 hrs. from time of hourly forecast ceiling will be 3500′, visibilty **9 miles,** no weather. In 5 hours from time of hourly forecast ceiling will be 3500′, visibility **9 miles** and strong, gusty, surface winds. In 9 hours the ceiling will be unlimited, visibility 9 miles, no weather.

**Where the number 9 is used in place of the ceiling height this indicates a ceiling over 9,750 feet.

(2) SWF WO x 1/2F 149/22/21 19/995/
Stewart AFB indefinite ceiling, sky obscured by fog, visibility ½ mile, fog, barometric pressure in millibars, 1014.9, temperature 22°F, dew point 21°F, wind north northeast, nineteen knots, fresh gusts, altimeter setting, 29.95 inches of mercury.

SECTION V - THE WEATHER MAP

1. INTRODUCTION

In any type of study, there is usually one report, chart, diagram, or some other device that indicates the over-all results of the study, a culmination of effort, so to speak. The student taking a master's degree writes

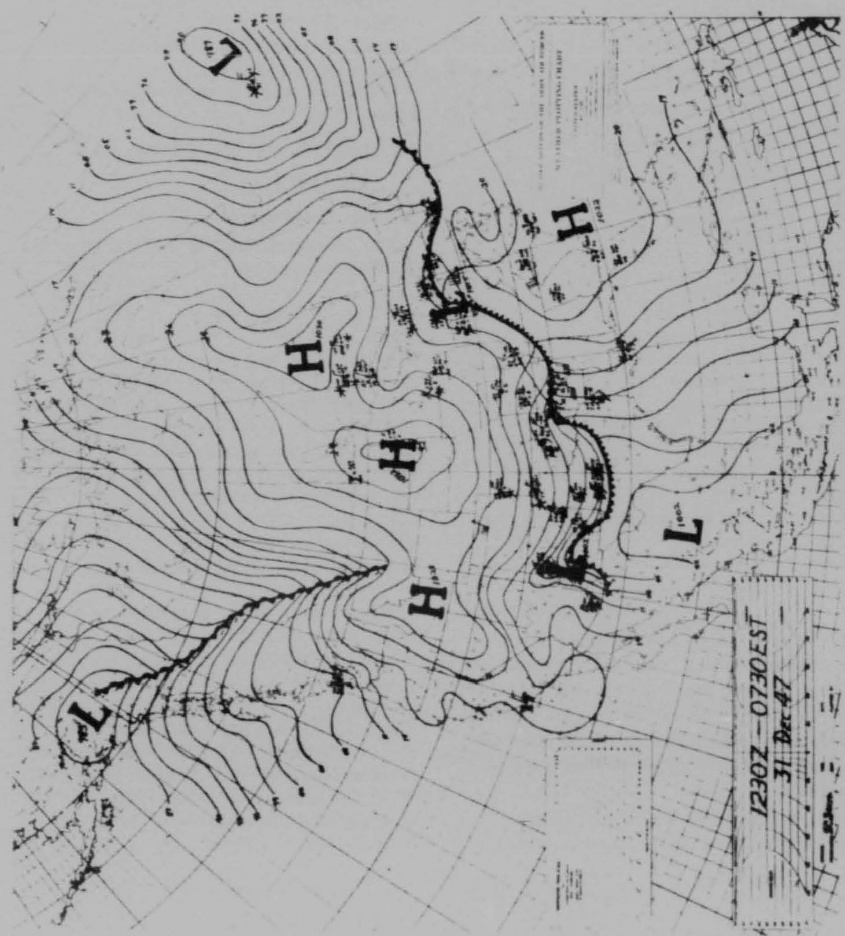


Figure 1-19 Synoptic Weather Map

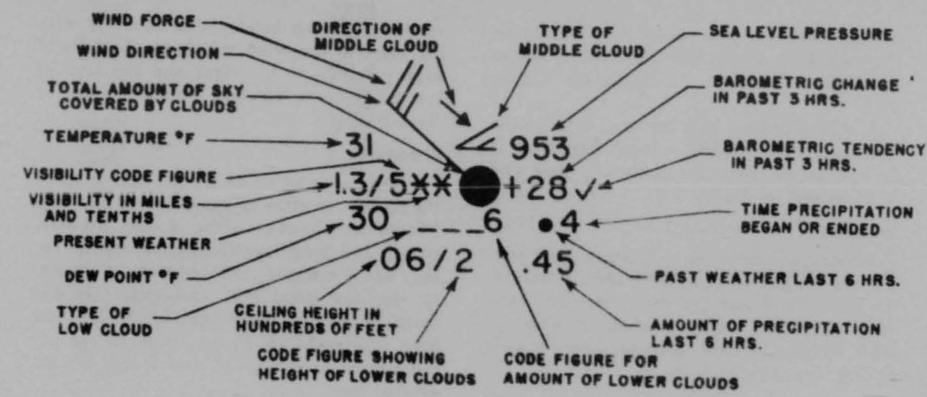


Figure 1-20 Station Circle

a thesis; the investigation board makes a report of its findings, and the statistician draws a graph depicting the results of his figures. In weather reporting and forecasting this final report appears in the form of a "weather map."

A weather map is a map of a given area which indicates all of the weather conditions in that area including the past six hours and present weather conditions at all of the reporting stations, location and type of fronts, precipitation and restriction to visibility, surface winds and atmospheric pressures. These weather conditions are shown in much the same manner that topographical conditions are shown on a relief map.

Beaufort Scale of Wind Force

BEAUFORT NUMBER	WEATHER MAPS	DECODE WIND DIRECTION	WIND SPEED MPH
0		CALM	LESS THAN 1
1			1 TO 3
2			4 TO 7
3			8 TO 12
4		S	13 TO 18
5			19 TO 24
6			25 TO 31
7			32 TO 38
8			39 TO 46
9			47 TO 54
10		NNE	55 TO 63
11			64 TO 75
12			ABOVE 75

Figure 1-21 Beaufort Scale

2. PREPARATION

Weather maps are prepared four times daily, once every six hours, and often are referred to as the six-hour weather maps. A special coded report is gathered from each station in the North American area to be included on the map and redistributed in such a manner as to allow each station to have a complete set of reports. These reports are then plotted on a blank map, and the forecaster will add other details such as fronts, highs, and lows. The finished product is known as a synoptic map, as shown in Figure 1-19. Many times a forecaster will draw a map in which he depicts the situation as he forecasts it six or twelve hours hence. Such a map is called a prognostic map.

3. WEATHER MAP INFORMATION

As previously stated, the weather map depicts most of the information gathered in the weather office.

Station Circle

The station circle shows weather information past and present as it is plotted on the map. This information is plotted by means of certain symbols as indicated in Figure 1-20.

It will be noticed that the wind is indicated by a symbol similar to a small flag. This is known as the Beaufort scale of winds and is explained in Figure 1-21.

Isobars

Isobars are lines on a weather map connecting points of equal sea level pressure. An isobar is drawn for each three millibars of pressure and indicates pressure levels in the same manner that contour lines indicate altitude on a relief map.

Highs and Lows

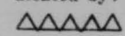
It will be noted on the map that the isobar indicating the highest pressure completely surrounds the point having a relatively high pressure. This point would be the center of an air mass and is known as a "high." The air flows around these highs in circular clockwise manner and they are often referred to as "anticyclones." Because the air tends to descend and move outward from a high, the air is relatively stable and good flying weather prevails.

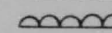
It also will be noted that the isobar indicating the lowest pressure in a system completely surrounds an area of relatively low pressure. This area is known as a "low." As would be expected in such a differential of pressure, air tends to move toward the center of a low and does so in a counter-clockwise circular manner. This circulation of air is known as a cyclone, or a cyclonic storm, and should not be confused with the smaller twisters properly termed tornadoes. Cyclones are usually hundreds of miles in diameter. Because the air within a low is ascending slightly, it is relatively unstable and poor flying weather prevails. Lows are indicated on weather maps by a large "L." If possible, this "L" is entered in red. Highs are indicated by a large "H" in blue.

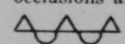
As indicated by the wind at various places along isobars on the illustrated map, the wind does not blow directly across the isobars from the highs to the low, but more or less flows parallel to them. This again is due to the Coriolis force. For this reason, a person on the northern hemisphere standing with his back to the wind will have the area of high pressure to his right and the area of low pressure to his left. This is known as Buys-Ballott's law.

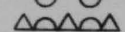
Fronts

Fronts are plotted on the weather map by the forecaster after he has observed the map. Fronts are located along a low pressure trough and their identification as to whether they are a warm or cold front is determined by the dew point and temperature behind them. It will be noted that in the weather map illustrated in Figure 1-19, fronts are not drawn in color, but cold fronts are indicated by:

 and warm fronts by:

. On such a map occlusions are indicated by a line:

 and stationary fronts by:

. Such indications of fronts are necessary whenever color printing is impossible or impracticable and is the way they usually appear in daily papers. It also will be noted that the cold fronts extend south and west from the lows and the warm fronts extend south and east from the low as indicated in Section III. Furthermore, a wave or occlusion is beginning to form in northern Oklahoma and Kansas.

Other Data

Other information included on a weather map is indicated in Figure 1-22. When possible, areas of precipitation are indicated in green. Steady precipitation is indicated in solid green and showery precipitation in hatched green. Fog areas are indicated in yellow.

4. SUMMARY

The weather map is one of the most valuable aids to flight planning available in the weather station. It is all-important in planning tactical operations. It is true that the latest weather is found on the sequence, and final flight decisions must be made from them, but it is from the weather map that one may visualize at a glance flying conditions over a large area.

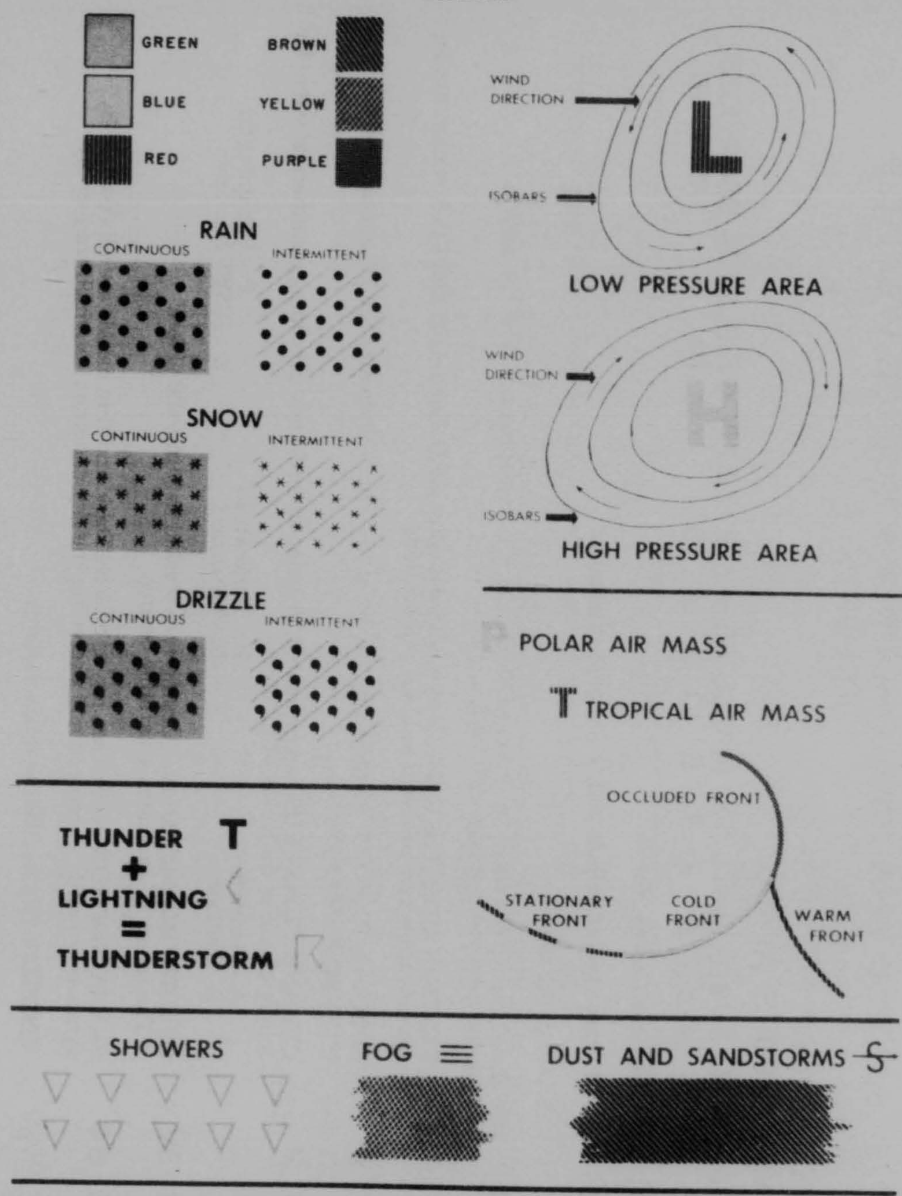


Figure 1-22 Symbols for Use on Weather Maps

SAMPLE ANALYSIS of HOURLY SEQUENCE WEATHER REPORTS

(A)	(B)	(C)	(D)
AWUS	9891-3	16	1430Z

TIK/S7/M/3V⊕⦶/1½V/L/FK/146/66/65/→3/997/E7⊕CIGVRBL2T04/05164/10332

1 2 3 4-5 6 7 8 9 10 11 12 13 14 15 16

(A) Air Weather United States

(B) The Military Circuit utilizes 9891, 2, 3, 4 as identification

(C) 16th Day of the month

(D) 1430 Zone time (Greenwich) In this case Mitchel A.F.B. Hempstead N.Y. is the station, making the time of the report 0930 EST

1. TIK · STATION IDENTIFICATION symbol for Tinker AFB. Each AFB and CAA station has an identification symbol listed in CAA publications.

2. S7 · SPECIAL REPORT, identified by the letter 'S'. The '7' indicates the 7th special observation for the day.

3. M · CEILING CLASSIFIED as measured. A letter immediately preceding a numerical value for ceiling classifies the value as follows:

A - Aircraft	E - Estimated	P - Precipitation
B - Balloon	M - Measured	W - Indefinite

4. 3V · CEILING is 300 ft. variable. Ceiling is expressed in hundreds of feet. The letter 'V' indicates a variable ceiling.

5. ⊕⦶ SKY CONDITION is overcast, lower broken. Dark and thin clouds are represented by symbols (+) and (−) respectively preceding the sky condition to which they apply.

6. 1½V · VISIBILITY is 1½ statute miles variable.

7. L · WEATHER is light drizzle. Weather is reported as follows:

T - Thunderstorms	L - Drizzle	S - Snow
A - Hail	R - Rain	SW - Snow showers
AP - Small Hail	Q - Squalls	ZL - Freezing drizzle
E - Sleet	RW - Rain showers	ZR - Freezing rain

8. FK · FOG AND SMOKE. The following symbols indicate obstructions to vision:

BD - Blowing dust	D - Dust	H - Haze
BN - Blowing sand	F - Fog	K - Smoke
BS - Blowing snow	GF - Groung fog	

9. 146 · SEA LEVEL PRESSURE is 1014.6 millibars.

10. 66 · TEMPERATURE is 66° F.

11. 65 · DEW POINT is 65° F.

12. →3 · WIND is from the West at 3 knots (CAA & WB stations report mph).

13. 997 · ALTIMETER setting is 29.97 inches.

14. E7⊕CIGVRBL2T04 · Estimated 700 ft. overcast. Ceiling is variable 200 to 400 ft.

15 & 16. TERMINAL FORECAST Code Groups, included only in reports from Air Force Bases. See Terminal Forecast poster for explanation.

The U. S. Weather Bureau circuit (See Fig. 1-17) which furnishes a teletype report dealing only with civil weather observation stations is identified as follows:

(1)	(2)	(3)	(4)
AW	3	16	0930E

(1) Airways Weather.

(2) (8003) Civil Code Number.

(3) 16th Day of the month.

(4) 0930 Eastern Standard Time.

Figure 1-23 Hourly Sequence Weather Report

CHAPTER 2 - NAVIGATION

1. GENERAL

The purpose of the navigation part of this book is to acquaint the prospective Air Force officer with some of the fundamental principles of navigation in order that he will better appreciate the problems involved when an airplane is flown from place to place. He will, thus, be better prepared to accomplish his own special assignment and thereby contribute more to the primary mission of the Air Force.

No attempt will be made to develop a practical navigator. The course in navigation is designed to be purely orientational.

Air navigation is the art of directing an airplane from one place to another and of determining its position at any time.

In its simplest form, air navigation is the guiding of an airplane by means of landmarks. The early-day flier found his way by following rivers and railroads and by watching for prominent towns and peaks much as a motorist finds his way by following the highway and by turning at the village church or the red barn.

This crude technique of navigating by landmarks was satisfactory for short daytime flights made within sight of the ground. But aircraft design progressed, production increased and traffic expanded. As air transportation grew in importance, the need arose for precise schedules to handle traffic by night as well as by day, over water as well as over land, and in foul weather as well as in fair. The old hit-or-miss method of navigation no longer was adequate; it had to be

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replaced by newer and more precise techniques.

In his attempt to improve the methods and instruments of air navigation, the airman logically turned to the long-established science of marine navigation. There he found much to borrow. Some of the precise equipment of the marine navigator, however, was too heavy and bulky for the airplane. Likewise, some of the marine navigator's techniques were too cumbersome and slow for use in a fast-moving airplane. Thus, it was imperative for the airman to design lighter, more compact equipment and simpler, quicker methods. Of course, some of the problems of air navigation had no close parallel in marine navigation. These problems had to be solved independently. Air navigation, therefore, progressed by the improvement of old instruments and methods and the invention of new.

A highly-organized system of government radio and lighting aids along the established airways of this country now makes possible the efficient operation of commercial airline schedules. These aids simplify the navigation problem, making it possible to navigate without a complete knowledge of the forces acting on the airplane. Consequently, on a commercial airliner the pilot and co-pilot can do their own navigation.

The navigation of military aircraft, however, is not quite so simple. These aircraft must fly where government aids may not be available. Furthermore, the pilot finds that maneuvering a bomber in formation demands his full attention. The navigator thus becomes an essential member of the crew.

Military airplanes fly several types of missions involving different navigational problems and techniques. The transport navigator is concerned with long, straightline flights, where fuel saving is a primary consideration. The bomber navigator must fly his course to avoid flak installations and enemy fighter bases. The Air-Sea Rescue navigator must make good a predetermined flight pattern in order to cover fully the area to be searched. But despite the differences in their problems, all these navigators have received the same navigational training, and all use basically the same methods. A navigator with a thorough knowledge of the basic principles of his craft can solve the special problems of any mission he may be required to fly.

The Navigator's Method

The navigator has three major problems. He must be able to determine the **position** of the airplane at any time, the **time** at which the airplane will reach any position, and the **way** to head the airplane to reach any desired destination.

The basic method used by the navigator to solve these three problems is called "dead reckoning," a term borrowed from the mariner and which means deduced reckoning. To solve each problem, the navigator must know certain facts. Thus, to find the position of an airplane by dead reckoning, he must know the **position** of the point of departure, the **direction** of flight, the **speed** of the airplane and the length of **time** it has been flying. Once these facts are known, the solution of the problem is very simple. For example, if an airplane has been flying due west from point "X" at a speed of 180 miles per hour for 20 minutes, its position obviously is 60 miles west of point "X." Finding the time an airplane will reach a given position is a variation of the same problem. The difficulty is not in solving these problems but in obtaining necessary facts as to speed and direction of flight.

The ever-present and never-predictable wind makes it difficult to determine the facts as to the airplane's speed and direction of flight. The airplane does not crawl along the earth's surface; rather, it flies through the air, which itself is moving across the earth. The navigator's instruments tell him how fast he is moving in relation to the air; but he may be flying faster or slower in relation to the earth, depending on whether he is flying with or against the wind. The wind affects not only the speed of flight but also its direction. Wind causes an airplane to drift away from the direction in which it is headed, just as a river carries a rowboat downstream as the boat crosses. The navigator's compass tells him the direction in which the airplane is headed but not the direction in which it moves over the earth.

The navigator's third problem is to de-

termine which way to head the airplane in order to reach a desired destination. This, too, is complicated by the wind. It is not enough to head the airplane in the direction of the destination, for the wind will blow it in a direction different from that in which it is headed. The wind's effect must be predicted and allowances made.

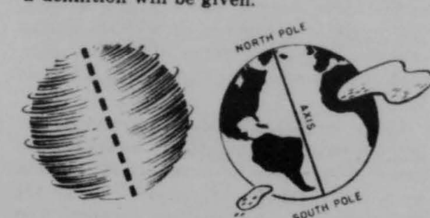
Clearly, a knowledge of the wind is very important to the navigator. The performance of his duties ordinarily demands that he keep track of the progress of the airplane and at the same time continually determine the wind.

Dead reckoning is never exact; small errors are bound to occur, and these small errors eventually add up to large errors. From time to time, therefore, the navigator must correct his dead reckoning by definitely locating his position in relation to the earth; he does this by using one of the aids to dead reckoning. Most simply, he may locate his position on a map by recognizing some landmark over which he is flying. If the ground is not visible, he may be able to find his position by the use of radio or by observation of the celestial bodies. Since the success of a mission may depend on any one of these aids, a skillful navigator must master the use of all of them as well as dead reckoning.

2. POSITION, DIRECTION, AND DISTANCE

General

Position, direction and **distance** on the surface of the earth are the very substance of navigation. Therefore, as a first step, the navigator must learn in what terms position, direction and distance are expressed. To make sure that they are all understood, a definition will be given.



The earth is a spinning ball. The imaginary line about which the earth spins is called the axis of the earth. The ends of the axis are called the north pole and the south pole.

The earth is not a perfect sphere. A sphere is a body whose surface is everywhere equidistant from a point within, called the center. Any line which passes from one side of a sphere through the center to the other side is a diameter of the sphere. Obviously, one diameter is equal to every other diameter.

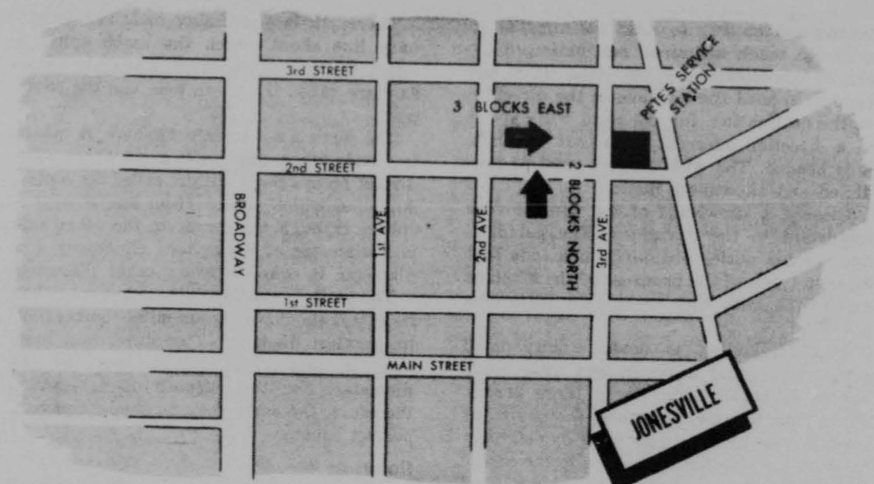
The earth is slightly flattened at the poles; its axis is about twenty-six miles shorter than its greatest diameter. This difference, however, is only about 0.3 per cent of the diameter. For the purpose of navigation, therefore, the earth may be thought of as a perfect sphere.

Position

It is necessary that some system be devised so that any **position** on the surface of the earth can be identified readily. Sometimes it may suffice to say that the airplane is ten miles east of Pittsburgh or that the destination is the Chicago Municipal Airport. That may be clear enough and simple enough. But how would the position of the airplane be designated on a trans-Atlantic flight? It would not be sufficient for the pilot to send in a position report saying that he was in the middle of the Atlantic or ten miles south of an iceberg. It is apparent that some universal method of expressing position without regard to nearby geographic features is needed.

If one were to tell a stranger the location of Pete's Service Station is Jonesville, he would say it is at the corner of Second Street and Third Avenue. This definitely tells the stranger the location, for there is only one place in all Jonesville where Second Street and Third Avenue cross. Or he may tell him that Pete's Service Station is two blocks north of Main Street and three blocks east of Broadway. This is just as definite. Quantities which give position with respect to two reference lines are called coordinates. Thus, "two blocks north" and "three blocks east" are the coordinates of Pete's Service Station relative to Main Street and Broadway.

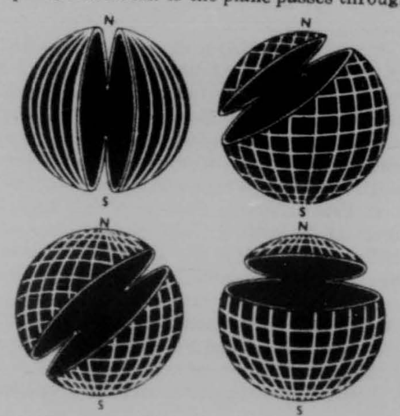
Positions on the earth may be given by



a similar system of coordinates. However, there are no natural lines on the earth to serve as reference lines. Therefore, it is necessary to use imaginary lines.

Straight lines usually are the most convenient to use. However, straight lines cannot be drawn on a curved surface. On a sphere, the most convenient reference line is a circle.

Circles on a Sphere. If a sphere is cut straight through, the cut edges are circles. Thus the intersection of a plane with a sphere is a circle. If the plane passes through the center of the sphere, dividing it in half, the circle formed is a great circle. A great circle is the largest circle which can be drawn on a given sphere. Any other circle, no matter what size, is called a small circle. The plane of a small circle of course, does not pass through the center of the sphere and hence does not divide it in half.

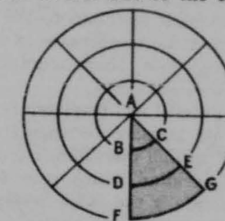


Segments of circles, or arcs, are measured in degrees, minutes, and seconds. A degree (°) is 1/360 of the circumference of a circle. Thus, if any circle is divided into 360 equal arcs, each arc is 1° in length, no matter what the size of the circle. A minute (′) is 1/60 of 1°; and a second (″) is 1/60 of 1′.

If a straight line is drawn from each end of an arc to the center of the circle, these two lines meet to form an angle at the center. This is the angle subtended at the center of the circle by the arc. Angles, like arcs, are measured in degrees, minutes, and seconds. The angle at the center of a circle always contains the same number of degrees, minutes, and seconds as the arc which subtends it.

Using degrees, minutes, and seconds of the arc, the length of any arc can be expressed; hence the distance between any two points on a circle can be expressed. This is not linear distance, but angular distance. The

angular distance between two points depends on what proportion of the circle separates them; the linear distance between them depends also on the size of the circle.



Reference Lines on the Earth. Circles make the best reference lines for designating position on a sphere. The question is where to draw the circles. A sphere is a continuous surface without beginning or end, and one point on it is just like another.

The only distinctive natural geometric line of the earth is its axis, which is different from every other diameter. Thus, the poles are distinctive points on the earth. The poles are used as the central points for one set of reference circles. The most important circle of this set is the equator.

The equator is the great circle halfway between the poles. Since the poles are 180° or half a circle apart, every point on the equator is 90° from each pole. The plane of the equator is perpendicular to the earth's axis. The equator divides the earth into a northern and a southern hemisphere just as Main Street divides Jonesville into a northern and a southern half. It serves as a reference line on the earth just as Main Street might serve as a reference line in Jonesville.

Any small circle whose plane is parallel with the plane of the equator is a parallel of latitude or simply a parallel. Each parallel is everywhere equidistant from the poles, from the equator and from every other parallel. Thus, the parallels and the equator are concentric about the polar axis.

Every point on the earth has a parallel passing through it. Only a few parallels are shown on a globe; for the globe would be solid black if they were all shown. A parallel is designated by its angular distance north or south of the equator; that is, toward the north or south pole.

A great circle passing through the poles is a meridian of longitude or simply a meridian. Meridians correspond to the north-south streets of Jonesville. But one meridian is just like another. None of them is a distinctive reference line corresponding to Broadway. Therefore, one meridian must be selected arbitrarily as a reference meridian or prime meridian. Different meridians have been used for this purpose. In English-speaking countries, and in many others, the meridian through the observatory at Greenwhich, near London, England, is used as the prime meridian.

Every point on the earth is on some meridian; as with parallels, however, only a few

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meridians are shown on a globe. A meridian is designated by its angular distance east or west of the Greenwich meridian, that is, right or left as one faces north.

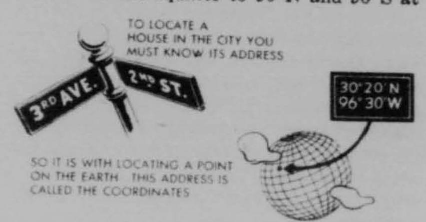
Latitude and Longitude. The parallels and meridians intersect at right angles to form a grid system comparable to the streets of Jonesville. A position in Jonesville can be designated by naming the streets which pass through it. Thus the 40°N parallel and the 75°10′W meridian together designate Philadelphia. Or a position in Jonesville can be designated by giving its coordinates relative to the two principal intersecting streets. Likewise, any point on the earth can be designated by giving its coordinates relative to the equator and the Greenwich meridian. These coordinates are called **latitude** and **longitude.**

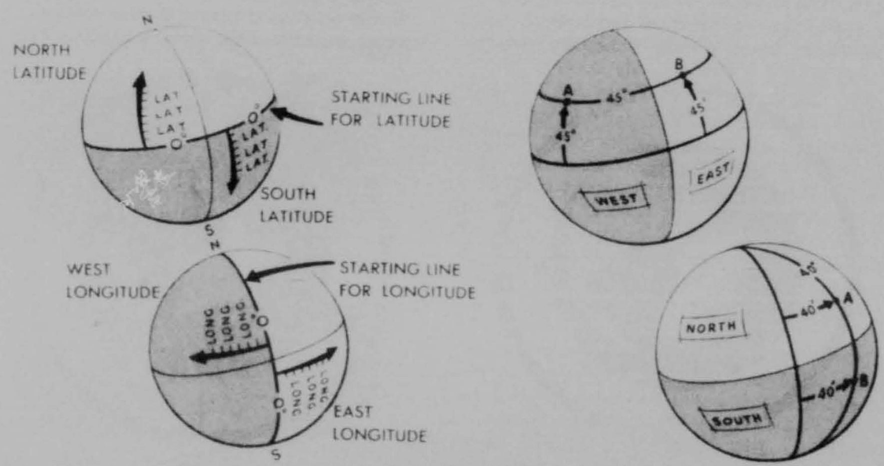
The latitude of a point is its angular distance north or south of the equator, measured in the plane of the meridian. Latitude ranges from 0° at the equator to 90°N and 90°S at the poles. **The longitude of a point is its angular distance east or west of the Greenwich meridian, measured in the plane of the equator or of a parallel.** Longitude ranges from 0° at the Greenwich meridian to 180°E and 180°W. In giving the coordinates of a point, latitude is given first, then longitude. For example, 29°03′S, 104°56′W.

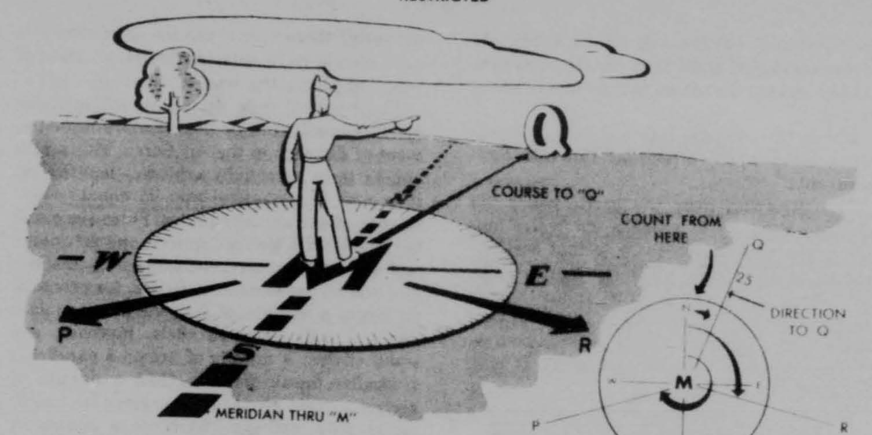
Since each parallel and meridian is named according to its angular distance from the equator or the prime meridian, naming the parallel and meridian which pass through a point is essentially the same as giving its coordinates. Note, however, that a meridian of longitude is a line; whereas longitude is an angle. Likewise, a parallel of latitude is a line; whereas latitude is an angle.

Direction

To walk across the street to the Jackson's house, a person would just glance at the house and start walking in that direction. He would seldom miss or get lost. But to fly







to Miami from Houston, he cannot use this simple method because he cannot see Miami from Houston. He would get the direction in some other way, usually from a map. Then he has the problem of keeping the airplane headed in the right direction. Obviously, direction is important in navigation. A system is needed for expressing the direction of any point from any other point.

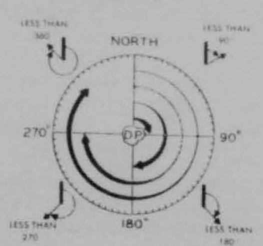
North is the direction of the north pole from any point on the earth, and south is the direction of the south pole. And as one faces north, east is to his right and west is to his left. There are only four of an indefinite number of possible directions. Some intermediate directions also have names, such as northeast, north-northeast, and northeast by north. But the number of named directions is small, and the names are cumbersome.

The system of direction used in navigation is much simpler, and it permits more exact designation of direction. Direction is expressed as an angle measured clockwise from north. At any position, one may imagine a circle whose circumference is divided into 360 equal units. If the divisions are numbered clockwise from north, they indicate true directions from the central point. The direction of north is 000° or 360°; East is 090°; south is 180°, and west is 270°.

The direction of Q and M is the angle from north clockwise to the line MQ. In other words, it is the angle between the meridian and MQ. The direction of Q is 025°. Likewise, the direction of R from M is 100°. And the direction of P from M is 260°.

A navigator must learn to think of directions as angles and practices estimating the directions of lines. Unless there is some device such as an arrowhead to show which way a line points, the line has two directions differing by 180°. Later, when he is measuring directions, he must be very careful not to make a 180° error. This is a serious mistake which is easy to make. He insures against this mistake by learning to estimate direction. Then he can check measurements by common sense. He can see at a glance that

Quadrant	*Boundaries*	*Directions*
1	North and East	000° to 090°
2	East and South	090° to 180°
3	South and West	180° to 270°
4	West and North	270° to 360°



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the direction of Q from M is about 025°. If it was measured as 205°, it would be apparent to him that the measurement was in error by 180°.

Divide the compass into quarters or quadrants. Note which directions fall into each quadrant:

The direction over the earth which an airplane must fly to reach a given destination is the true course (TC) to that destination. It is often simply called "course." The line which the airplane must follow across the earth or across the map to reach its destination also is called course or true course. Where necessary to avoid ambiguity, it may be called the TC line.

The direction of a line on the earth is the angle it makes with the meridians it crosses. The meridians themselves, of course, run north and south. The equator and parallels of latitude, which intersect all meridians at right angles, run east and west. Except for the equator and the meridians, every great circle intersects successive meridians at different angles. That is, the direction of the great circle changes from place to place on the earth.

It follows that any line which crosses successive meridians obliquely at the same angle cannot be a great circle. Such a line is a line of constant direction or rhumb line. The equator, the parallels and the meridians also are lines of constant direction; and loosely, they too are called "rhumb lines." However, they are complete circles; whereas a true rhumb line extended indefinitely on the earth is a spiral curve which approaches, but never reaches, the poles.

Any two points on the surface of the earth may be connected by a great circle arc. Any two points not at the same latitude or longitude also may be connected by a rhumb line.

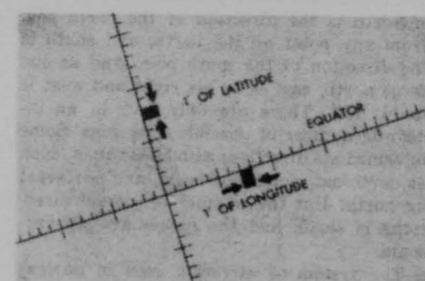
Steering by compass, it is easier to fly in a constant direction than to change direction uniformly. Therefore, the **course line** which is **easiest** to follow **is a rhumb line** and **not a great circle.** Thus, true course means rhumb-line course.

Distance

It is common knowledge that distance may be expressed in feet or miles. The ordinary mile or statute mile contains 5,280 feet. Apparently, there is no good reason why the mile should have this particular number of feet, but that's the way it is.

The nautical mile (n.m.) which contains 6,080 feet will soon be the standard measurement of distance in the Air Force. This might appear to be an equally arbitrary length; but it is not. The nautical mile is equal to one minute of arc on the equator. Since the earth is considered a perfect sphere, the meridians and the equator are considered as great circles and all the same size. Hence, for practical purposes, a minute of latitude also equals a nautical mile. The parallels, however, are small circles. A minute of arc on a parallel is a smaller linear distance than a minute of arc on a great circle; furthermore its length varies with latitude. Therefore, a minute of arc on a parallel is not a nautical mile.

There is no absolute rule that nautical miles must be used to navigate. Usually nautical miles are more convenient, and this is especially true in celestial navigation. Sometimes, however, there is a good reason for using statute miles. Just be sure not to mix the two systems of measurement; that is courting confusion. In this section nautical miles are used almost entirely.

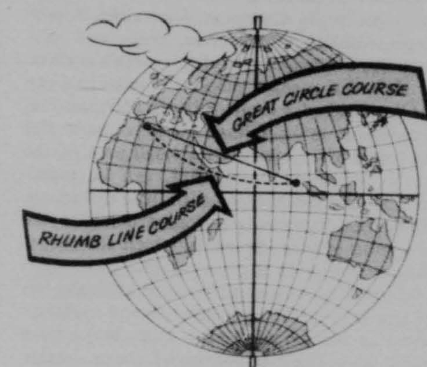


Great-circle Distance. The shortest distance between two points is a straight line. But a straight line cannot be drawn on the curved surface of the earth. The shortest distance between two points on the earth lies along the great circle passing through these points. There are two arcs of the great circle connecting these points; the shorter arc is the great-circle distance. The shorter arc of the great circle between two points is more nearly a straight line than is the arc of any

other circle which can be drawn on the earth between these points.

Through two points "A" and "B," draw two circles of different sizes. Obviously, the shorter arc of the larger circle is more nearly a straight line than the arc of the smaller circle. The larger the circle, the more nearly this arc will approach a straight line, and hence the shorter the distance along it between "A" and "B." Remember that a great circle is the largest circle which can be drawn on the earth.

Because the shortest distance between two



points is a great circle arc, one might think that an airplane should always fly the great-circle course from departure to destination. In low and middle latitudes and over short distances, however, the rhumb-line distance between two points is not much greater than the great-circle distance. The saving in distance would not repay the trouble of following a great circle. Ordinarily, the rhumb-line course will be flown and the great-circle course will be ignored.

On long flights at high latitudes, however, the rhumb-line course may be considerably longer than the great-circle course. Compromise is made by flying a series of rhumb-lines which approximates a great circle.

3. MAPS AND CHARTS

General

A map is a graphic representation of a portion of the earth's curved surface projected upon a plane surface. A map prepared especially for use in navigation is often called a chart. Formerly, when all navigation was on the sea, charts were of water areas with coastlines. Now, however, air-navigation charts show details of land areas as well as water areas. In air navigation the terms "map" and "chart" both are used.

Charts are important navigational equipment. On a chart the navigator keeps track of the airplane's position and measures the true course and distance to destination from the departure point and from other positions established en route.

Scale

Obviously, maps are much smaller than the areas which they represent. The ratio between length on a map and the true distance it represents on the earth is the scale of the map. The scale may be relatively uniform over the whole map, or it may vary greatly from one part of the map to another.

Maps are made to various scales for different purposes. If a map is to show the whole world and yet not be too large, it must be drawn to a small scale. If a map is to show much detail, it must be drawn to a large scale; then it shows a smaller area than a small-scale map of the same size. Remember: large area, small scale; small area, large scale.

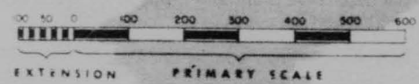
The scale of a map may be given by a simple statement, such as, "one inch equals ten miles." This of course means that any-

thing actually ten miles long is shown one inch long on the map. On aeronautical charts, the scale is indicated in one of two ways.

Representative Fraction

The scale may be given as a representative fraction, such as, 1:500,000 or 1/500,000. This means that one of any unit on the chart represents 500,000 of the same unit on the earth. For example, 1 inch on the chart represents 500,000 inches on the earth.

A representative fraction can be easily converted into a statement of miles to the inch. Thus, if the scale is 1:1,000,000, 1 inch on the chart stands for 1,000,000 inches or $\frac{1,000,000}{6080 \times 12}$ nautical miles = about 13.7 n.m. Similarly, if the scale is 1:500,000, 1 inch on the chart represents about 6.85 n.m. Thus, the larger the denominator of the representative fraction, the smaller the scale.



Graphic Scale

The scale may be shown by a graduated line. This is merely a distance as it appears on the map labeled in terms of the actual distance it represents on the earth.

The distance between parallels of latitude is a convenient graphic scale, for it is known that 1° of latitude always equals 60 n.m. Often the meridian is divided into minutes of latitude, which of course equal nautical miles.

4. MAP MAKING AND PROJECTION

General

The surface of the earth may be truly represented only on a globe. Because the globe has the same shape as the earth, directions, distances, shapes, and areas all may be shown faithfully.

For some purposes, a globe is the most useful representation of the earth's surface. For other purposes, however, a globe is inconvenient because of its shape and its bulk. To be useful in navigation, a globe must be of large scale in order to show detail. However, a large globe cannot be carried conveniently; nor would sections of a globe be easy to handle. Consequently, navigational charts are always printed on flat sheets of paper.

Distortion

A spherical surface cannot be spread out on a plane; it is said to be nondevelopable. A complete orange peel cannot be flattened without tearing, stretching, or wrinkling it. Likewise, the surface of the earth cannot be represented perfectly on a flat surface. There is bound to be distortion. **Distortion is misrepresentation of direction, shape and relative size of the features of the earth's surface.**

Note that a small piece of orange peel can be flattened with comparatively little tearing, stretching or wrinkling; for it is nearly flat to begin with. Likewise, a small area of the earth, which is nearly flat, can be represented on a flat surface with little distortion. Distortion becomes a serious problem in the mapping of large areas, in which the curvature of the earth is pronounced.

Distortion cannot be avoided entirely, but it can be controlled somewhat and systematized in the drawing of a map. Maps have many uses. If a map is drawn for a particular purpose, it can be drawn to minimize the type of distortion which is most detrimental to that purpose.

Before considering how maps are made, consider what characteristics are desirable in a map.

The Perfect Map

There are several requirements which a map should meet. These might be called the characteristics of a perfect (but impossible) map:

The scale should be constant over the whole map.

Angles should be truly shown. If this is done, shapes will be portrayed accurately, at least in small areas.

Great circles should be shown as straight lines. A great circle is the shortest distance between two points on a sphere, and a straight line is the shortest distance between two points on the map.

A rhumb line, or line of constant direction, should be shown as a straight line. This is the line which an airplane tends to follow when steered by compass.

Certain additional characteristics, though less important, also are desirable:

The coordinates of points should be easy to find from the map; and a point should be plotted easily on the map when its coordinates are known.

Maps of adjacent areas drawn, to the same scale, should be joined easily.

Each cardinal direction always should point the same way on every part of the map. Thus a north-south line on one part of the map should parallel a north-south line on any other part of the map.

The map should be simple and easily constructed.

Equal areas should be shown as equal. If the scale were constant over the whole map, areas necessarily would be shown correctly. However, areas may be shown correctly when the scale is not constant.

Since the perfect map is impossible, all these desirable characteristics cannot be combined in one map. In fact, it is obvious that certain of these characteristics are mutually exclusive. It is possible, however, to construct a map meeting one of these requirements which is especially important for the purpose of the particular map. And, it is possible to construct a map which fulfills several of these requirements, or which, by compromise, approaches the fulfillment of several of them.

Map Making

The exact coordinates of any point on the earth may be found by astronomical means. Then, with reference to control points established in this way, the location of nearby features may be found by surveying or by aerial photography. A map is made by drawing the geographic features on a framework of meridians and parallels known as a graticule. Once the graticule is drawn, features may be plotted in their correct positions with reference to the meridians and parallels.

The construction of the graticule is a very critical step in map making. The form of the graticule determines the general characteristics and appearance of the map; and, of course, its size determines the scale. Since the meridians and parallels cannot be shown on a plane surface exactly as they would appear on a sphere, there is no one correct way of constructing the graticule. In fact, there is no limit to the number of ways in which the graticule may be drawn. For example, the meridians and parallels may be shown as straight lines, as variously curved lines, or some as straight and some as curved lines; they may be spaced in various ways; and they may intersect at various angles. Actually, the graticule always is drawn in some systematic manner.

Projection

The process of constructing the graticule is called projection. Also, each type of graticule is called a projection. In actual practice, the graticule is drawn on a plane sheet of paper in accordance with certain mathematical principles which differ with the type of projection.

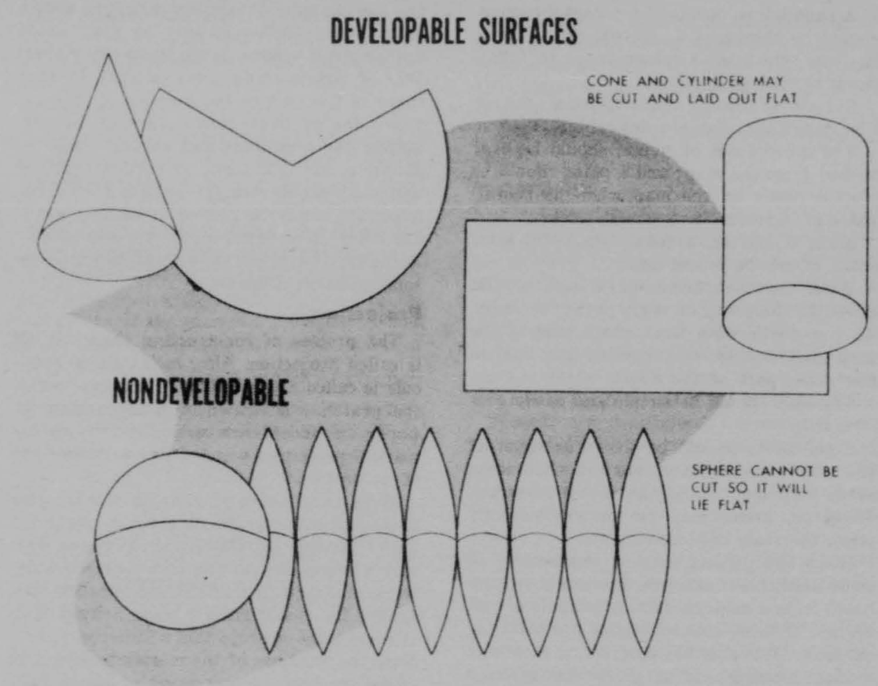
With certain map projections, it is possible to visualize the graticule actually projected onto the paper as if by a magic lantern. Picture a sphere consisting of a hollow framework of opaque meridians and parallels, say at 30° intervals. Then picture a light bulb at some point of projection within the sphere. Now the shadows of the meridians and parallels are cast on any sheet of paper held outside the sphere. In other words, the graticule is projected onto the paper.

The exact pattern of the graticule depends on the position of the point of projection and the position of the sheet of paper. Note that the surface on which the projection is made need not be plane. It can be a cone or cylinder, which can be unrolled into a plane after the projection is made. A cone or cylinder is a developable surface in contrast to the nondevelopable surface of the sphere.

If the map is visualized as actually projected onto a developable surface from some point within the sphere, one can gain an understanding of the principles of the projection. However, it is important not to forget that the projection actually is drawn on a plane sheet of paper.

Some map projections cannot be explained as projections from a point onto a developable surface. Other projections can be explained in this manner only with the as-

DEVELOPABLE SURFACES



sumption that the point of projection changes its position for different parts of the map. In any case, the term "projection" is used for the construction of the graticule.

Classes of Projections

It is not possible to classify projections so that each falls into only one category. However, there are several more or less overlapping classes which are sometimes useful.

Conformal Projections. In these projections, angles are correctly shown. Since the meridians and parallels intersect at right angles on the earth, they intersect at right angles on a conformal chart. Scale is uniform in all directions from any point; but it is not necessarily uniform at two different points on the map. Hence, shapes are correctly shown within a small area, but shapes of large areas may appear distorted.

The two projections most used in air navigation are conformal. These are the Lambert conformal conic projection and the Mercator projection. Likewise, the stereographic projection is conformal.

Perspective Projections. In perspective projections (geometrical projections), the point of projection is fixed. Usually the projection is made on a plane tangent to the earth. Examples are the gnomonic and stereographic projections.

Azimuthal Projections. In these projections, the direction of every point from the central point on the map is correctly shown. This is true of all polar projections, though it is not especially important in navigation. Sky diagrams are on an azimuthal projection.

Equal Area Projections. In these projections, equal areas are shown as equal, though at the expense of conformality. Thus, shape is not retained. This projection is of small interest in navigation.

Conventional Projections. These are certain arbitrary projections. They ordinarily are not used in navigation.

Projections used in navigation. Charts are used in navigation principally for two purposes; map reading and plotting and measuring. **Map reading is location of position by the indentification of landmarks by means of a chart. Plotting is the establishment of points and lines on a chart;** and measurement here means the measurement of direction and distance on the chart.

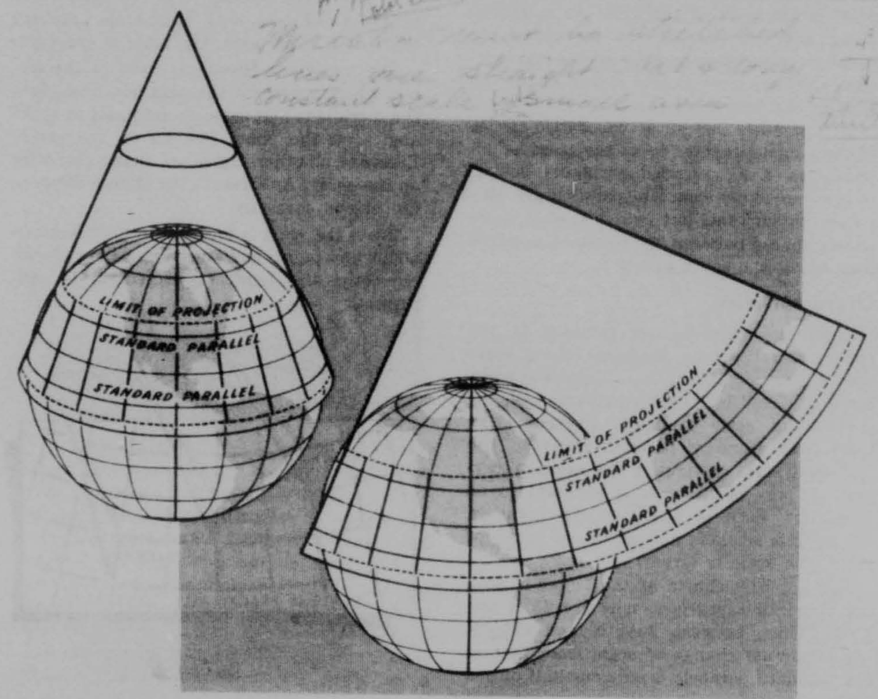
The charts most used for map reading are on the Lambert conformal conic projection. Those most used for plotting and measuring are on the Mercator projection. The stereographic projection and the gnomonic projection have special uses in navigation. Other projections also may be used; but these four are the most important.

5. LAMBERT CONFORMAL CONIC PROJECTION

General

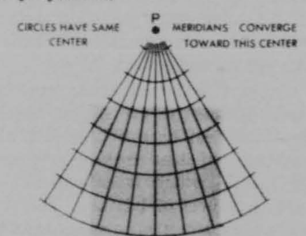
Charts of the Lambert conformal conic projection may be called simply "Lambert charts." Although other projections also bear the name of the cartographer Lambert, they are not used in navigation.

The Lambert conformal conic projection is not a true perspective projection, but it can be understood best by thinking of it as one. One may think of it as projected on the surface of a cone which intersects the earth along two parallels of latitude. The axis of the cone coincides with the axis of the earth. The apex of the cone thus lies on an extension of the earth's axis, above the north pole if the area to be mapped is in the northern hemisphere. The point of projection is on the earth's axis, but it does not remain in the



same position for all parts of the map.

The parallels along which the cone intersects the earth are called the standard parallels. Their selection depends on the latitude of the area to be mapped. They are about one-sixth of the distance from the top and bottom of the projection.



Appearance of the Graticule

The meridians appear as straight lines which converge toward a point off the top of the chart, (Northern Hemisphere). This point is the apex of the cone. As measured along any one parallel, the meridians are equally spaced; but because of the converg-ence, they are more closely spaced at the top than at the bottom of the chart.

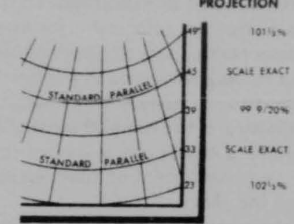
The parallels appear as concentric circles whose common center is at the point of intersection of the extended meridians, that is, at the apex of the cone. The parallels are very nearly equidistant, but are somewhat more closely spaced between the standard parallels than north and south of them.

Characteristics

Since the parallels are common to the sphere and the cone, elements along these lines are represented truly in shape and scale. Since all parallels are not equally spaced, the north-south scale gradually changes away from each standard parallel. However, the east-west scale changes in the same proportion. At any point, scale is constant in all directions. Between the standard parallels, the scale is smaller; and north and south of them, the scale is larger.

For Lambert charts of the Unted States, the standard parallels usually are 33°N and 45°N. Then, between 30½°N and 47½°N the maximum change of scale from that at the standard parallels is only one-half of one per cent. The maximum change of scale for the whole chart is 2½ per cent in southern Florida.

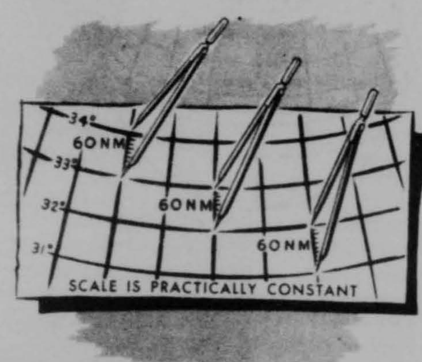
VARIATION OF SCALE ON A LAMBERT PROJECTION

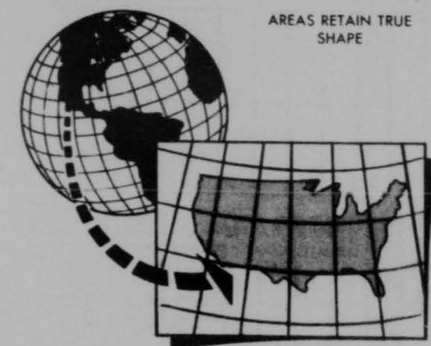


A large-scale Lambert chart of a portion of the United States is just a section of a large chart of the whole area. Thus, the standard parallels of the sectional chart are the same as those of the chart of the whole area. Though there is some change of scale over the whole area, the change is negligible over any small portion of it. Therefore, for practical purposes, on a large-scale Lambert chart of a small area, the scale is constant.

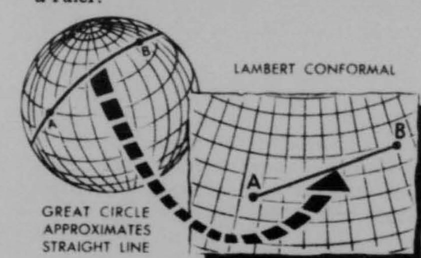
The meridians appear as radii of the circles which represent the parallels. Therefore the meridians and parallels intersect at right angles on the chart just as on the earth. Likewise, all other angles are shown correctly on the chart. As a result, the shapes of areas are shown correctly.

Since the scale is uniform in all directions about any point, and since angles are shown correctly, the Lambert projection is conformal.





Any straight line on a Lambert chart is very nearly a great circle. In the distance of 2,572 statute miles between San Francisco and New York, the great circle and the straight line connecting them on a Lambert chart are only 9½ miles apart at the mid-longitude. For shorter distances, the departure is less than proportional. Thus, for all practical purposes, if it is only a few hundred miles long, a straight line is a great circle. This is convenient since it enables the shortest line between two points to be drawn with a ruler.



A rhumb line is a curved line on a Lambert chart. The more nearly its direction is east-west, the more a rhumb line departs from a straight line. Over distances of one or two hundred miles in the latitude of the United States, a rhumb line departs little from a straight line; but over long distances the departure is large. Between San Francisco and New York, the rhumb line departs about 170 miles from the straight line. An accurate rhumb line cannot be drawn easily on a Lambert chart, but it can be approximated by a series of straight lines.

Use

Scale variation increases with the width of latitude covered by the Lambert projection. Therefore this projection is most suitable for comparatively narrow latitude bands; it is ideal for the United States. However, there is no limit to the width of longitude which may be covered with no effect on scale; the projection may extend around the earth.

The constant scale and the conformality of Lambert charts place them among the very best navigational charts. For problems involving distances and true directions, they are superior to Mercator charts. They are suitable for use with long-distance radio-bearings. For plotting positions and measuring rhumb-line directions, they are somewhat inferior to Mercator Charts; but the difference is not necessarily great or important.

6. MERCATOR PROJECTION

General

The Mercator projection is not a true perspective projection. It best can be understood by following the steps that one might make in making a Mercator chart from a very elastic world globe. First, the surface of the globe is cut along the meridians to form a series of gores. Then the surface of the globe is peeled and laid flat on a table. It is now a good map except for its resemblance to a picket fence: the gores are connected along the equator but separated above and below, leaving blank spaces. To fill these gaps, each gore is stretched sidewards. The higher the latitude, the more the gaps are stretched to make them meet. Now a map has been made with no north-south distortion but with east-west distortion which increases with latitude. As a last step, it is necessary to make the scale uniform in a north-south and an east-west direction at every point on the map. Therefore the map is stretched in a north-south direction so that at each latitude the amount of north-south stretching is the same as the amount of east-west stretching.

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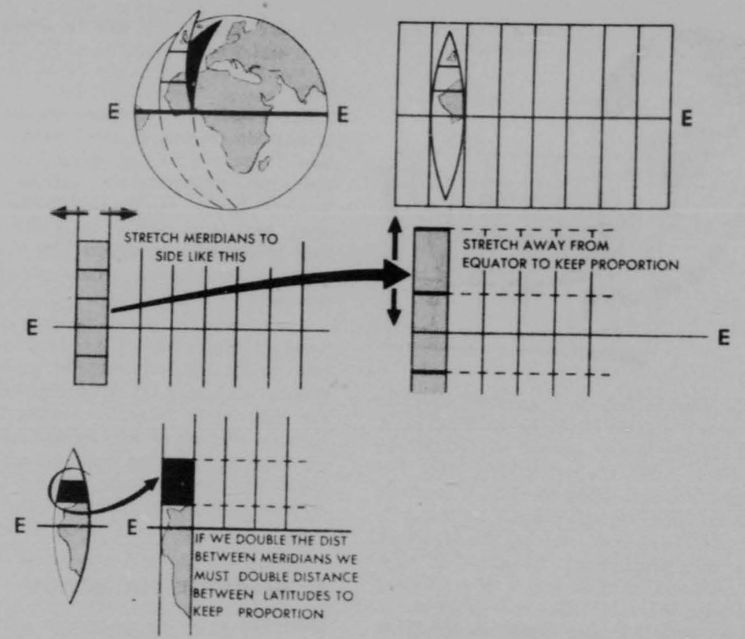


Appearance of the Graticule

The meridians appear as vertical straight lines which are equidistant and parallel. The parallels of latitude appear as horizontal straight lines which thus are parallel to one another and perpendicular to the meridians. Their distance apart increases with latitude.

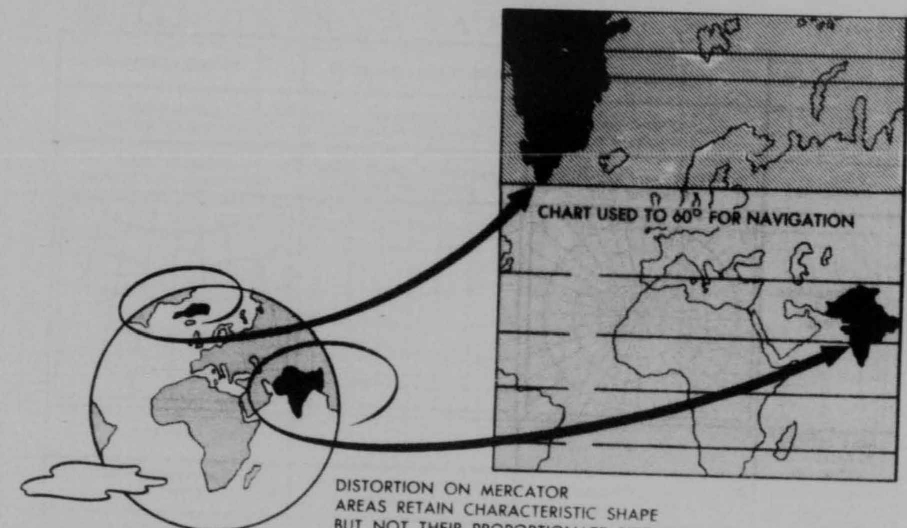
Characteristics

On the earth, meridians converge toward the poles; yet on the Mercator chart, they appear as parallel. Meridians which are 10 miles apart at the equator are only 5 miles apart at the 60° parallel; yet on the chart they appear equally far apart throughout their length. On the chart, therefore, the east-west scale is increased so that it is twice as great at the 60° parallel as it is at the equator. Consequently, the parallels must be so spaced on the chart that the north-south scale increases in the same proportion. Thus parallels, which are the same distance apart everywhere on the earth, are shown twice as far apart at 60° as at the equator. Their distance apart increases progressively with their distance from the equator. As a result, the scale at any point is constant in all directions.

The meridians and parallels are shown as intersecting at right angles on the chart just as on the earth. Likewise, all other angles are shown correctly. This means that shapes are shown correctly within small areas, though the expanding scale causes distortion of shape over large areas.

Since scale is uniform in all directions at any point, and since angles are correctly shown, the Mercator projection is conformal.

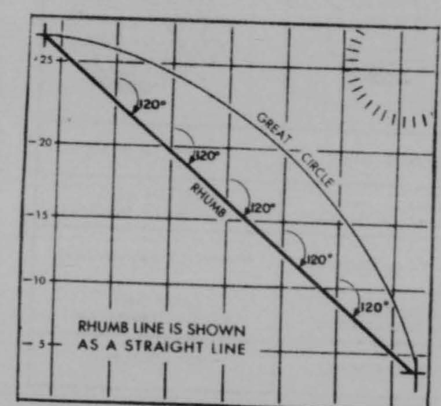
A rhumb line or line of constant direction crosses every meridian at the same angle. Since angles are correctly shown on a Mercator chart, a rhumb line is shown crossing every meridian at the same angle. Because the meridians appear as parallel lines, any line crossing them at a constant angle must be a straight line. On a Mercator chart, therefore, every line appears as a straight line, and every straight line is constant in direction. The Mercator projection is unique



DISTORTION ON MERCATOR
AREAS RETAIN CHARACTERISTIC SHAPE
BUT NOT THEIR PROPORTIONATE SIZE

among all projections in having this characteristic. Since the airplane tends to follow a rhumb line, it is a great advantage to be able to draw a rhumb line as a straight line.

The equator and the meridians are the only great circles which appear as straight lines on a Mercator chart. They, of course, are the only great circles which are also lines of constant direction. All other great circles appear as curved lines, which cannot be drawn easily.



Use

The Mercator chart is the standard navigational chart of mariners; it also has great value in air navigation. The greatest advantage of a Mercator chart is the fact that a rhumb line is a straight line. There are other advantages.

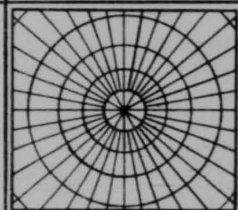
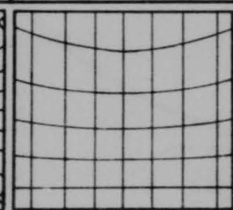
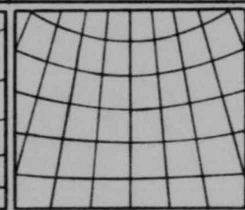
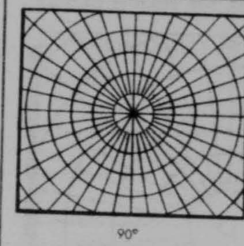
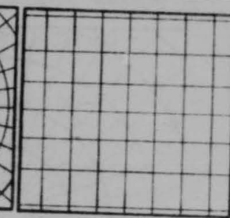
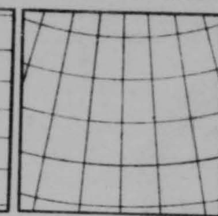
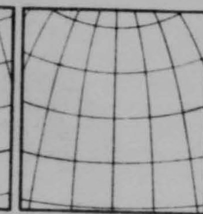
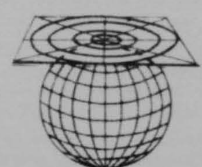
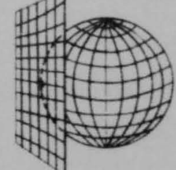
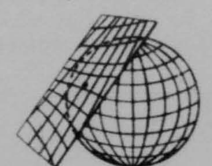
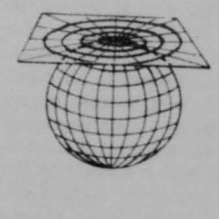
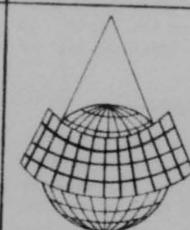
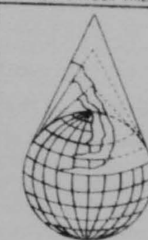
Plotting is easier on a Mercator than on any other navigational chart because the graticule is rectangular. The cardinal directions are the same on every part of the chart. Thus a north-south line is always parallel to the sides of the chart, and an east-west line is always parallel to the bottom. All Mercator charts are similar; charts of adjacent regions drawn to the same longitude scale will fit together exactly. Lastly, the chart is easily constructed.

Long-range radio bearings cannot be plotted on a Mercator chart without special corrections. In this respect Mercator charts are inferior to Lambert, polar stereographic, and gnomonic charts.

The expanding scale of the Mercator chart is a great disadvantage in navigation. This

RESTRICTED

SUMMARY OF PROJECTIONS

CHARACTERISTIC	POLAR GNOMONIC *	EQUATORIAL GNOMONIC	OBLIQUE GNOMONIC	POLAR STEREOGRAPHIC	MERCATOR	LAMBERT CONFORMAL	POLYCONIC
PARALLELS	CONCENTRIC CIRCLES UNEQUALLY SPACED	CURVED LINES UNEQUALLY SPACED	CURVED LINES UNEQUALLY SPACED	CONCENTRIC CIRCLES UNEQUALLY SPACED	PARALLEL STRAIGHT LINES UNEQUALLY SPACED	ARCS OF CONCENTRIC CIRCLES NEARLY EQUALLY SPACED	ARCS OF NON-CONCENTRIC CIRCLES EQUALLY SPACED ON MID-MERIDIAN
MERIDIANS	STRAIGHT LINES RADIATING FROM THE POLE	PARALLEL STRAIGHT LINES UNEQUALLY SPACED	STRAIGHT LINES CONVERGING AT THE POLE	STRAIGHT LINES RADIATING FROM THE POLE	PARALLEL STRAIGHT LINES EQUALLY SPACED	STRAIGHT LINES CONVERGING AT THE POLE	MID-MERIDIAN STRAIGHT OTHER CURVED
APPEARANCE OF GRID							
ANGLE BETWEEN PARALLELS & MERIDIANS	90°	VARIABLE	VARIABLE	90°	90°	90°	VARIABLE
STRAIGHT LINE CROSSES MERIDIANS	VARIABLE ANGLE (Great Circle)	CONSTANT ANGLE (Great Circle)	VARIABLE ANGLE (Great Circle)	VARIABLE ANGLE (Approximates Great Circle)	CONSTANT ANGLE (Rhumb Line)	VARIABLE ANGLE (Approximates Great Circle)	VARIABLE ANGLE (Approximates Great Circle Near Mid Meridian)
GREAT CIRCLE	STRAIGHT LINE	STRAIGHT LINE	STRAIGHT LINE	APPROXIMATED BY STRAIGHT LINE	CURVED LINE (Except Equator and Meridians)	APPROXIMATED BY STRAIGHT LINE	APPROXIMATED BY STRAIGHT LINE NEAR MID-MERIDIAN
RHUMB LINE	CURVED LINE	CURVED LINE	CURVED LINE	CURVED LINE	STRAIGHT LINE	CURVED LINE	CURVED LINE
DISTANCE SCALE	VARIABLE	VARIABLE	VARIABLE	NEARLY CONSTANT EXCEPT ON SMALL SCALE CHARTS	MID-LATITUDE	NEARLY CONSTANT	CONSTANT FOR SMALL AREAS VARIABLE FOR LARGER AREAS
GRAPHIC ILLUSTRATION							
ORIGIN OF PROJECTORS	CENTER OF SPHERE	CENTER OF SPHERE	CENTER OF SPHERE	OPPOSITE POLE	CENTER OF SPHERE (For Illustration Only)	CENTER OF SPHERE	CENTER OF SPHERE
DISTORTION OF SHAPES & AREAS	INCREASES AWAY FROM POLE	INCREASES AWAY FROM POINT OF TANGENCY	INCREASES AWAY FROM POINT OF TANGENCY	INCREASES AWAY FROM POLE	INCREASES AWAY FROM EQUATOR	VERY LITTLE	INCREASES AWAY FROM MID MERIDIAN
METHOD OF PRODUCTION	GRAPHIC OR MATHEMATICAL	GRAPHIC OR MATHEMATICAL	GRAPHIC OR MATHEMATICAL	GRAPHIC OR MATHEMATICAL	MATHEMATICAL	GRAPHIC OR MATHEMATICAL	MATHEMATICAL
NAVIGATIONAL USES	GREAT CIRCLE ROUTE DETERMINATION	GREAT CIRCLE ROUTE DETERMINATION	GREAT CIRCLE ROUTE DETERMINATION	POLAR NAVIGATION. ALL TYPES	DEAD RECKONING AND CELESTIAL (Suitable for All Types)	PILOTAGE AND RADIO (Suitable for All Types)	GROUND FORCES MAPS
CONFORMALITY	NOT CONFORMAL	NOT CONFORMAL	NOT CONFORMAL	CONFORMAL	CONFORMAL	CONFORMAL	NOT CONFORMAL BUT IS USED AS SUCH ON VERY LARGE SCALE MAPS

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can be overcome by using a scale which is an average for the latitude band in which the measuring is done.

The scale of a Mercator chart expands slowly in the vicinity of the equator and rapidly in polar latitudes. The Mercator projection is best suited for use within 15° or 20° of the equator. At latitudes above 70° or 80° it has little value.

7. POLAR STEREOGRAPHIC PROJECTION

General

The polar stereographic projection is a true perspective projection. It is made on a plane tangent to the earth at the pole. The point of projection is the opposite pole. Stereographic projections often are made with other points of tangency, but these are not much used in navigation.

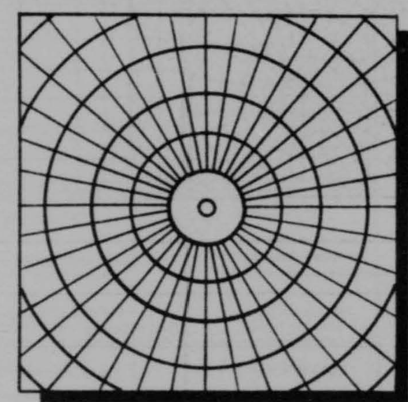
Appearance of the Graticule

The pole appears at the center of the projection. The meridians appear as straight lines radiating from the pole. The angle between any two meridians is equal to their difference of longitude. The parallels appear as circles concentric about the pole. Their distance apart increases somewhat with their distance from the pole.

Characteristics

A stereographic map may include a whole hemisphere. However, the polar stereographic charts used in navigation do not extend more than about 20° or 30° from the pole. The characteristics given here are those of a polar stereographic navigational chart; they would not apply so well to the outlying portions of a hemisphere map.

Since the interval between parallels increases slightly with their distance from the pole, the north-south scale also increases away from the pole. The east-west scale increases in the same proportion, so that at any point the scale is constant in all directions. Within the limits of the navigational chart, the scale changes little. In fact, for all practical purposes, the scale is constant.



Since the meridians appear as radii of the circles representing the parallels, the meridians and parallels intersect at 90° on the chart just as on the earth. It is also true that all other angles are correctly shown.

Because the scale is uniform in all directions about any point, and because angles are correctly shown, the polar stereographic projection is conformal. Another characteristic of the projection is that a circle on the earth always appears as a circle on the chart.

Meridians which are great circles, appear as straight lines. Hence, any great circle passing through the center of the chart appears as a straight line. Other great circles appear as slightly curved; but the closer they are to the center, the more nearly straight they appear. Within the limits of a navigational chart, for all practical purposes, a great circle is shown as a straight line.

Rhumb lines appear as curved lines.

The characteristics of a polar stereographic chart are very similar to those of a Lambert

chart. This is not surprising, for the polar stereographic projection may be thought of as the extreme case of the Lambert projection, with the cone flattened out into a plane.

Use

The polar stereographic chart is perhaps the best chart for navigation in polar regions. The Mercator chart, of course, is completely useless in these latitudes.

8. GNOMONIC PROJECTION

General

The gnomonic projection is a true perspective projection made on a plane tangent to the earth. The point of projection is at the center of the earth and therefore lies in the plane of every great circle on the earth. As a result, every great circle is projected as a straight line. This is the most important fact concerning the gnomonic projection.

Appearance of the Graticule

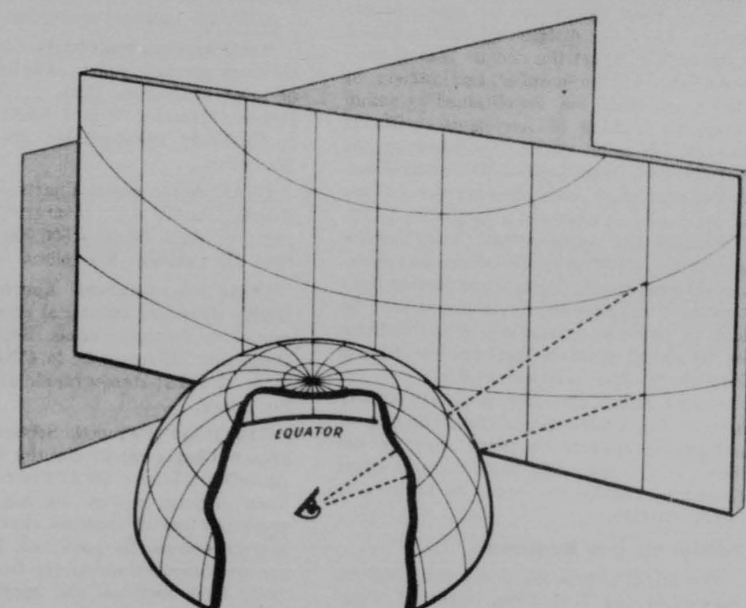
The equator and the meridians, being great circles, always appear as straight lines. The parallels, not being great circles, always appear as curved lines (ellipses or circles).

The general appearance of the graticule depends on the point of tangency. If either pole is the point of tangency, the graticule looks somewhat like that of a polar stereographic. The meridians appear as straight lines radiating from the pole at the center of the chart. The parallels appear as circles concentric about the pole; but their distance from the center increases rapidly. The equator would be infinitely far from the center.

If the point of tangency is on the equator, the meridians appear as nonequidistant, parallel straight lines. They are perpendicular to the equator, which is also a straight line. The parallels appear as unequally-spaced nonparallel curves which are bowed toward the equator at the center of the projection.

If the point of tangency is between the equator and the pole, the meridians appear as convergent straight lines. The parallels appear as unequally-spaced, nonparallel curves which are bowed toward the equator along the central meridian. The central mer-

PLANE TANGENT AT THE EQUATOR



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idian intersects the equator and parallels at right angles.

Characteristics and Use

The scale of a gnomonic projection increases rapidly away from the point of tangency. And it is not constant in all directions about any point except the point of tangency. Therefore distances are difficult to measure, and areas are not shown correctly. Shapes and angles also are misrepresented. Plotting of points is difficult because of the irregularity of the graticule. In short, the gnomonic chart has few merits. On a gnomonic chart, every straight line is a great circle. Therefore the shortest line between two points can be found by laying a ruler between the two points and connecting them with a line. The principal use of the gnomonic chart is in planning great-circle routes.

9. AERONAUTICAL CHARTS

General

The charts used in the Air Force are supplied by Base Operations or some similar agency. They are distributed by the USAF Aeronautical Chart Service in Washington.

An idea of the number and variety of charts published, may be obtained by examining the Catalog of Aeronautical Charts and related publications, published by the Aeronautical Chart Service. The catalog contains index maps, each showing the outlines of the published charts of a particular series.

Because the Aeronautical Chart Service constantly is publishing new charts and revising old ones, the catalog must be revised from time to time. Between revisions, it may be kept up to date by reference to the Bulletin of New and Revised Aeronautical Charts Published, which is issued weekly.

United States aeronautical charts usually are revised at least once a year. The date of publication appears on every chart in the lower left corner. The date on any chart should be checked in order to be sure it is not obsolete.

Sectionals and Regionals

For several years the Coast and Geodetic Survey of the U.S. Department of Commerce has published aeronautical charts of the United States. **Those on a scale of 1:500,000 are known as Sectional Charts. Those on a scale of 1:1,000,000 were known as Regional Charts.** These regional charts are no longer published; their place has been taken by the World Aeronautical Charts on the same scale.

Since no other suitable terms existed, the terms "sectional" and "regional" were extended to include similar charts published by other agencies. Thus, a sectional chart or a sectional is an aeronautical chart on a scale of 1:500,000 designed especially for map reading. Similarly, a regional chart or a regional is an aeronautical chart on a scale of 1:1,000,000 designed especially for map reading.

Charts of the World

The following list gives the most important aeronautical charts which are available for all parts of the world. A few other series are listed in the Catalog of Aeronautical Charts and related publications.

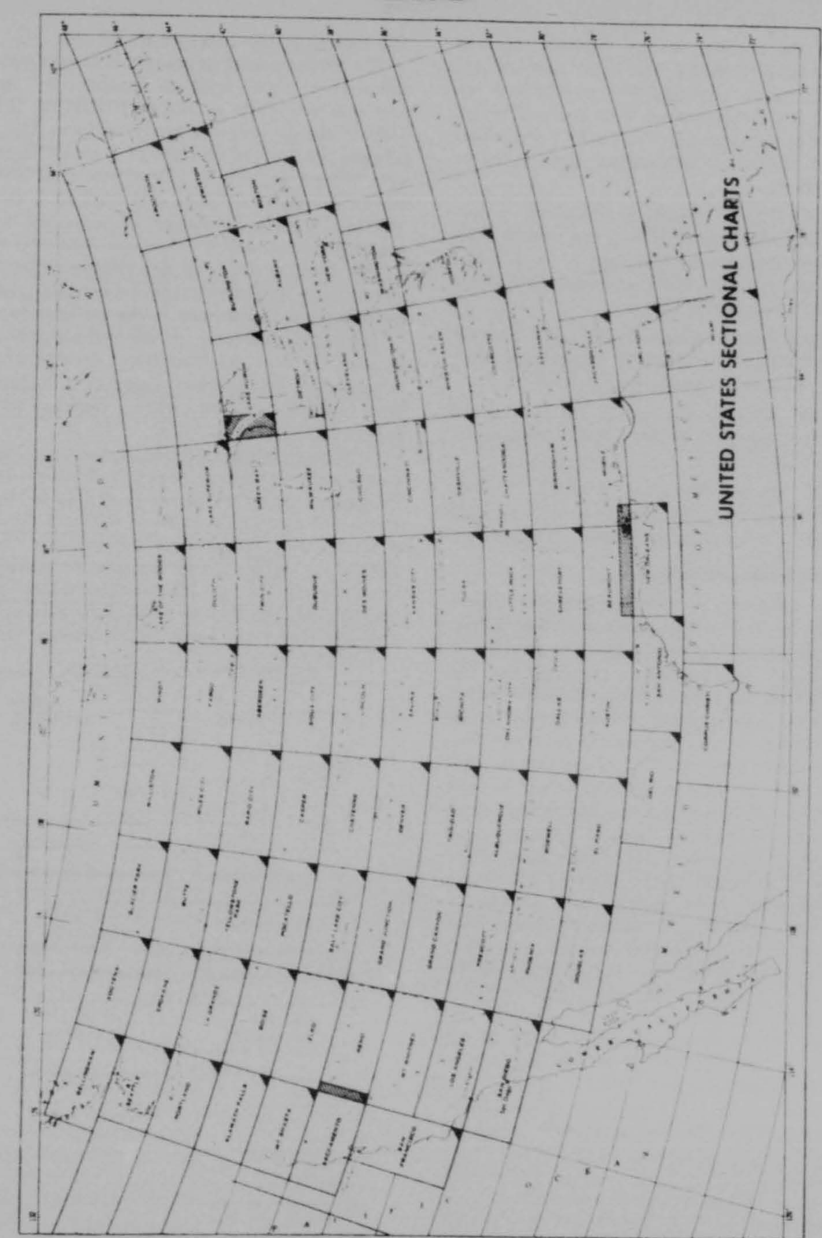
U.S. Planning Chart. One for the United States (from a complete world series). Scale 1:5,000,000. Lambert projection. Five colors.

World Aeronautical Charts. Complete world coverage planned; charts have been published of most land areas. Scale 1:1,000,000. Projection: Mercator 0° to 4°N&S; Lambert 4° to 72°N&S; stereographic above 72°N&S. Six colors.

USAF Aeronautical Charts. (USAF Sectionals). Partial world coverage; thus far only parts of Asia. Scale 1:500,000. Projection: thus far Lambert. Six colors.

USAF Aeronautical Approach Charts. Highly developed industrial centers and congested or strategic areas. Scale 1:250,000. Projection: Mercator 0° to 4°N&S; Lambert 4° to 72°N&S; stereographic above 72°N&S. Six colors.

The USAF Regional, Sectional, and Approach Charts constitute the USAF World Aeronautical Chart (WAC) or regional series. Each regional covers the same area as 4 sectionals and 16 approach charts, though all are not necessarily published. The regionals are numbered consecutively from 1 to about 1800. Each sectional and approach chart is



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given the number of the regional, part of whose area it shows. The sectionals and approach charts covering the area of one regional are distinguished from one another as shown in a diagram. On the back of each chart is a world map which serves as an index to the series.

USAF Flight Charts. Strips showing certain important air routes. Scale mostly 1:1,000,000. Projection: Mercator 0° to 4°N&S; Lambert 4° to 72° N&S; stereographic above 72°N&S. Six colors (average).

USAF Plotting Charts. 70°N to 70°S. Scale 1:3,000,000 at 37°N or S. Projection: Mercator. One color, graticule only.

USAF Plotting Charts. 17 for the United States. Scale 1:1,000,000 Mercator projection. Five colors.

U.S. Radio Direction Finding Charts. (RDF Charts). 6 for the United States. Scale 1:2,000,000. Lambert projection. Seven colors.

Chart Interpretation

An aeronautical chart is a diagram of part of the earth's surface. As a diagram, it does not picture all details; rather, it emphasizes particular features which are useful to the airman. It represents those features which have the most distinctive apearance when seen from the air. For emphasis, many features are shown out of all proportion to their true size, though centered in their correct positions. For example, the line representing a road on a regional chart may appear to be a quarter of a mile wide if measured in the scale of the chart. Radio stations are shown prominently, even though they are inconspicuous from the air. Moreover, many lines—such as meridians and parallels, isogonics, airways, and contours—take up space on the chart even though they are quite invisible from the air. Because of this necessary emphasis of important features, there is not room on the chart for all details visible from the air, especially in congested areas.

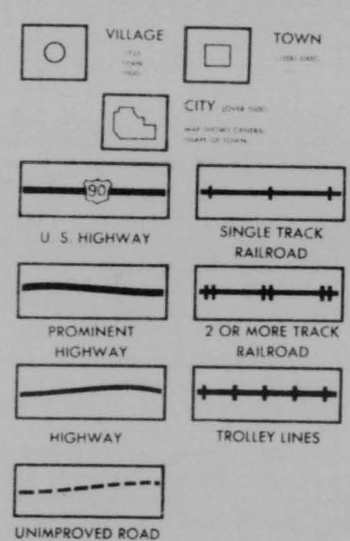
Since a chart is a diagram, it consists of symbols which do not necessarily resemble the shape or appearance of the objects they represent. Skill in map reading will depend upon the ability to understand and interpret these symbols. One must learn to visualize the terrain as one looks at the chart.

The symbols used on one set of charts may differ from those used on another; but on any one set, such as the sectionals of the United States, they are fairly uniform. Usually on the margin or back of a chart there is a legend or key to the symbols. If one learns to read sectionals and regionals, one will find it easy to change, if necessary, to another type of chart.

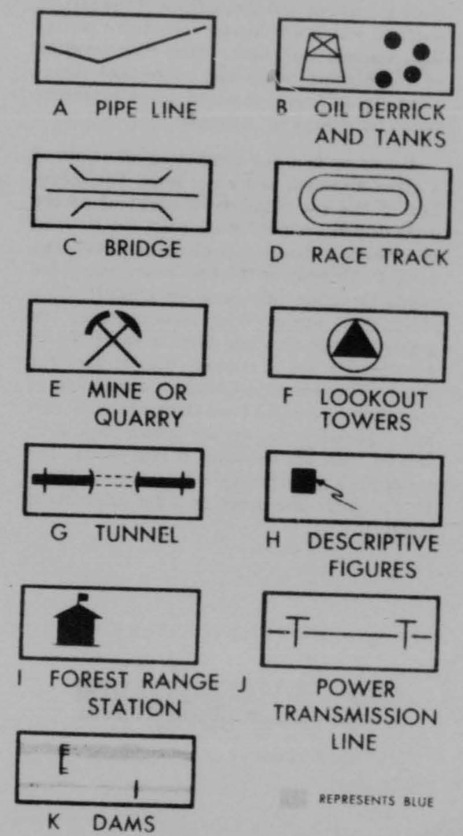
The symbols used on aeronautical charts fall roughly into two classes: **topographic and aeronautical. Topography is the configuration of the earth's surface,** including the position of such features as cities, lakes, forests, and mountains. Topographic features fall into four classes: **culture, water, forests, and relief.**

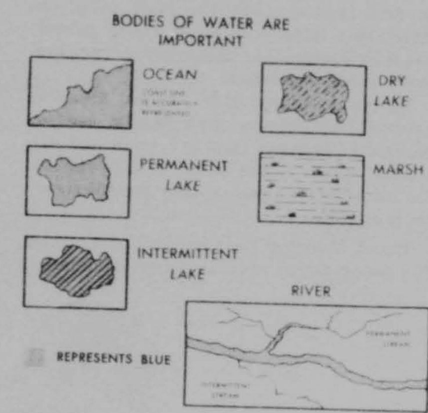
Cultural symbols represent man-made features such as towns, roads, and railroads. Cities and towns are shown according to size by several symbols. A circle or square denotes a small town, but it does not indicate the town's shape. The town can be recognized from the air only by its position relative to nearby features, such as roads, railroads, and streams. One must learn by experience just

CULTURAL (MAN-MADE) FEATURES



MISCELLANEOUS CULTURAL FEATURES





how big a town looks from the air when it is shown by a circle on the chart, and how big when shown by a square. A city, on the other hand, is represented more nearly in its true shape, and to scale.

Roads and railroads usually are conspicuous from the air. Railroads are particularly useful to the navigator since all railroads are shown on the aeronautical chart. On regional charts, comparatively few roads are shown; and even on the more detailed sectional charts many conspicuous roads are omitted, especially in congested areas. In addition, railroads usually are more permanent roads and are more likely to be shown accurately. It is sometimes difficult to distinguish between roads and railroads when seen from high altitudes. Remember that railroads do not have sharp turns. The chart may or may not show bridges, but one usually can expect to see a bridge where a road or railroad is shown to cross a stream.

Many cultural features, such as race tracks, oil fields, tank farms, and ranger stations, are shown by special symbols. There are no standard symbols for certain other conspicu-

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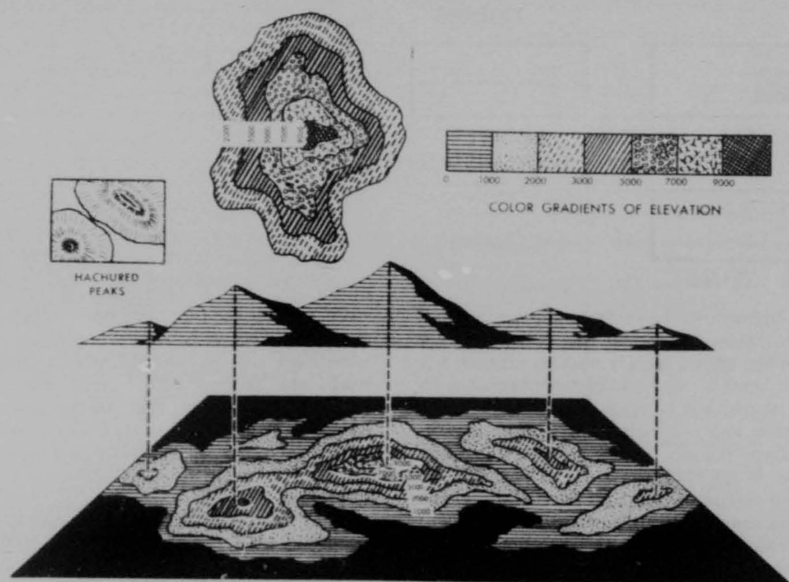
ous features, such as smoke stacks, water towers, monuments, and prominent buildings. These often are indicated by brief descriptive notes, each with an arow and perhaps a dot showing the location.

Water and Forest Symbols. Bodies of water are valuable to the navigator because they are relatively permanent; they are seen easily by day and often by night. Coastlines may be shown accurately, even though inland areas are little explored and poorly mapped. Conventionally, water is shown in blue; but this does not mean that it looks blue from the air. In arid regions, even the most important rivers may have little water above ground; but their courses may be marked by comparatively dense vegetation.

European charts show forest areas in green. These forests often can be used as landmarks because they are small and distinctive in shape and do not change rapidly. In this country, however, they are not shown on the charts.

Relief. Mountains are important to airmen for two reasons: they are good landmarks; and they are hazards to flying. Consequently, aeronautical charts make some attempt to show elevations and inequalities of the earth's surface, which are known collectively as relief. Aeronautical charts often give elevation of the highest peaks and other spot elevations. In addition, most of them represent relief by means of contours.

A contour is a line connecting all points of a given elevation above sea level. The shoreline of the sea might be thought of as the 0-ft. contour, since every point on it is at an elevation of zero feet above sea level. The 1,000-ft. contour is the line where the shore would be if the tide came up 1,000 ft. On a steep slope contours are close together; on a gentle slope they are farther apart. To an experienced eye, a contour map is just the same as a relief map, and it is possible to visualize the terrain from them. On sectionals and regionals, contours are brown lines, each labeled with the elevation it represents. The lower ones are drawn for intervals of 1,000-ft. elevation; the upper ones for intervals of 2,000 ft.



AERONAUTICAL SYMBOLS

LANDPLANE FACILITIES

LANDPLANE BASE—MILITARY (COMPLETE FACILITIES)

LANDPLANE BASE—CIVIL (COMPLETE FACILITIES)

LANDPLANE AIRPORT—MILITARY (REFUELING & LIMITED REPAIR FACILITIES)

LANDPLANE AIRPORT—CIVIL (REFUELING & LIMITED REPAIR FACILITIES)

FLIGHT STRIP (LIMITED OR NO FACILITIES)

LANDING FIELD (LIMITED OR NO FACILITIES OR LOGISTIC INFORMATION NOT AVAILABLE)

SEAPLANE FACILITIES

SEAPLANE BASE—MILITARY (COMPLETE FACILITIES)

SEAPLANE BASE—CIVIL (COMPLETE FACILITIES)

SEAPLANE BASE—JOINT MILITARY & CIVIL (COMPLETE FACILITIES)

SEAPLANE AIRPORT—MILITARY (REFUELING & LIMITED REPAIR FACILITIES)

SEAPLANE AIRPORT—CIVIL (REFUELING & LIMITED REPAIR FACILITIES)

SEAPLANE AIRPORT—JOINT MILITARY & CIVIL (REFUELING & LIMITED REPAIR FACILITIES)

SEAPLANE EMERGENCY ANCHORAGE (LIMITED OR NO FACILITIES OR LOGISTIC INFORMATION NOT AVAILABLE)

THE LENGTH OF LONGEST RUNWAY IN FEET IS INDICATED BY THE INNER CIRCLE OF EACH SYMBOL THUS

2500-3499 · 3500-4499 · 4500-5499
5500-6500 · OVER 6500 · LENGTH UNKNOWN

LIGHTING FACILITIES

AVIATION ROTATING BEACON

AVIATION ROTATING BEACON WITH COURSE LIGHTS

AVIATION ROTATING BEACON WITH CODE BEACON (NON-DIRECTIONAL)

AVIATION FLASHING BEACON

AVIATION BEACON FLASHING CODE

OBSTRUCTION LIGHT

NIGHTLIGHTING FACILITY — LF

LIGHTS (SURFACE NAVIGATIONAL)

LIGHTSHIP

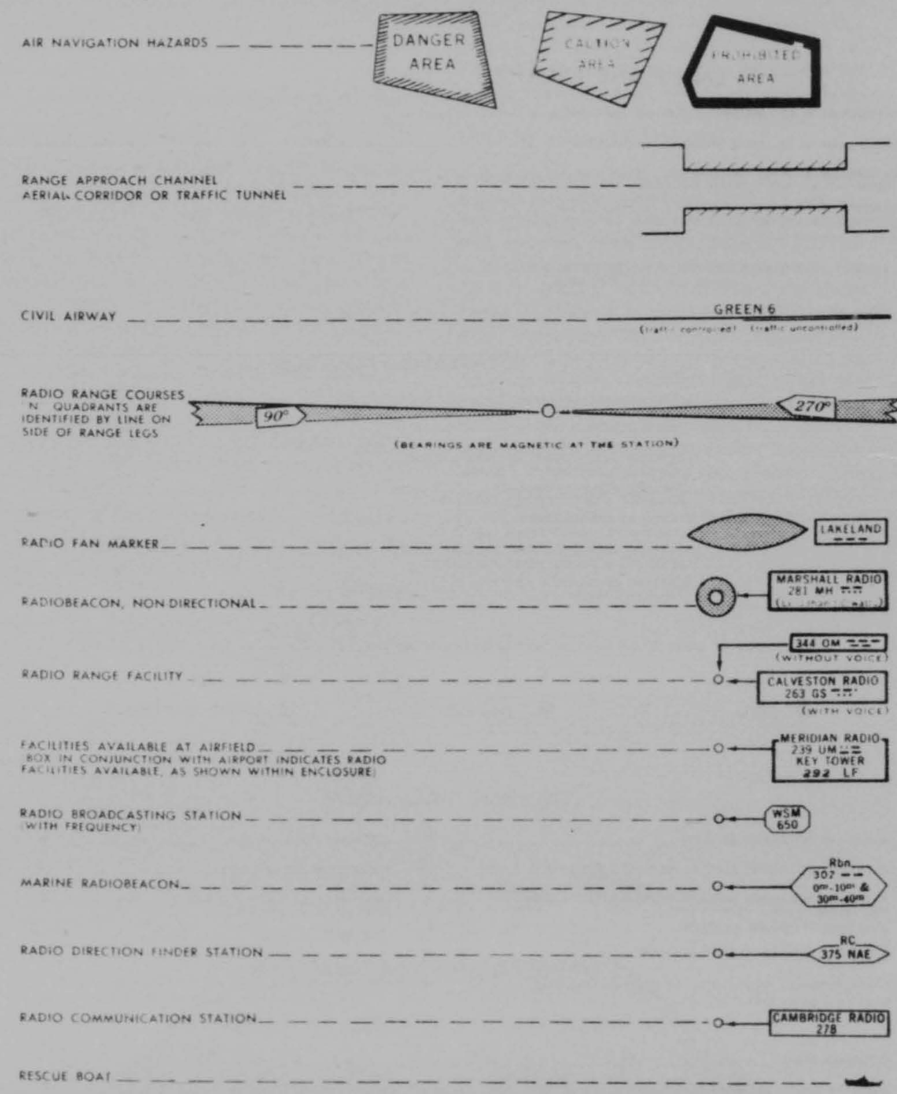
F fixed, Fl flashing, Occ-occulting, Alt-alternating, Gp-group, R-red, W-white, G-green, B-blue, Sec-sector.

Alternating lights are red and white unless otherwise indicated.
Lights are white unless colors are stated. Heights of lights are above high water.

MOORING MAST

LINES OF EQUAL MAGNETIC VARIATION — 7°W

AIR DEFENSE ZONE OR VITAL DEFENSE AREA — BOUNDARY OF VITAL DEFENSE AREA



The relief shown by contours is further emphasized on sectional and regional charts by a gradient system of coloring. The area between sea level and the 1,000-ft. contours is dark green; that between the 1,000-ft. and 2,000-ft. contours is light green. The areas between successive higher contours are in different shades of brown, from light to dark. The darker-colored mountain peaks stand out conspicuously, even to someone who is not experienced at reading contours. Other series of aeronautical charts have different color schemes, and still others have only the contours.

On charts of poorly known areas, mountains may be indicated by hachures or shading lines, with the elevations of peaks given as accurately as they are known. Hachures may be used on contour charts to show prominent hills, or buttes too small to show up otherwise because of the large contour interval.

Aeronautical Symbols. Aeronautical information is printed in red or purple on sectional and regional charts. Classes of airports are distinguished by different symbols, and the elevation of each airport is given. Light beacons are shown with their code signals. Also shown are the locations of radio stations, with call letters and frequency, and the position of each radio beam. Airways, danger areas, and isogonic lines are clearly marked.

10. BASIC NAVIGATION PROCEDURE AND INSTRUMENTS

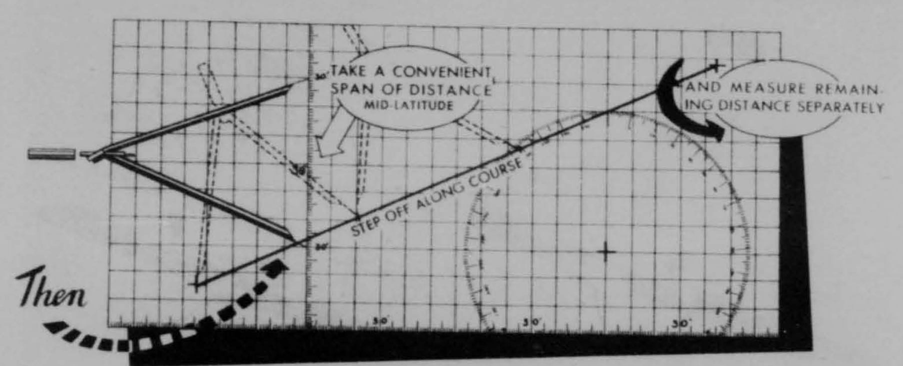
Plotting and Measuring

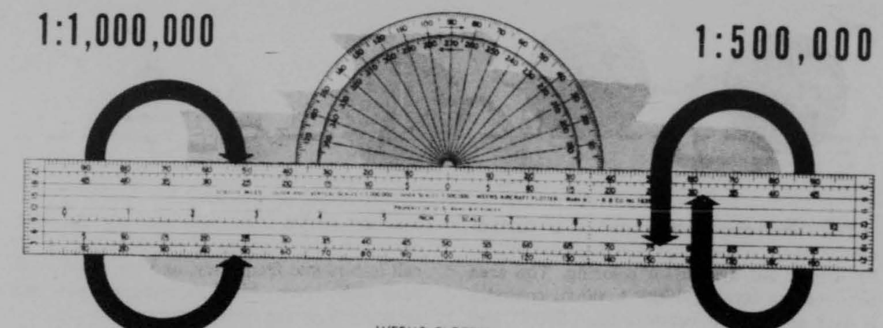
General. Plotting and measuring are basic operations in navigation. **Plotting is the establishment of points and lines on a chart with reference to the meridians and parallels.** Measurement here means the measurement of direction and distance on a chart.

Pencil, eraser, dividers, and plotter are used in plotting and measuring. Sometimes a long ruler and a triangle are found to be useful. A navigator must learn to use these instruments automatically.

Measurement of Distance. The distance between two points on a chart is usually measured by use of dividers. However, a ruler, string, or some other divider will do just as well.

It is important to remember when measur-





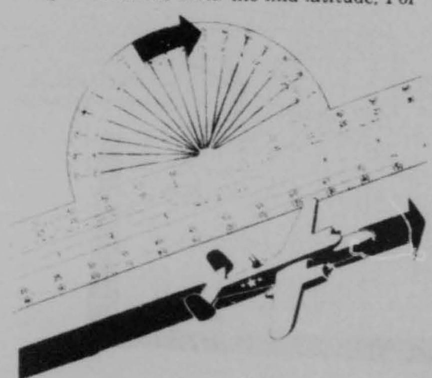
WEEMS PLOTTER

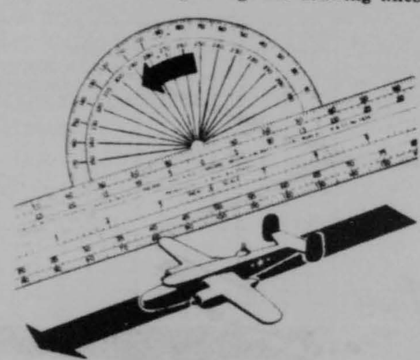
ing distance that distance scales vary with each type of projection. The distance scale on a Lambert conformal projection is constant and should give very little difficulty. But the distance scale varies with latitude on the Mercator projection, so it is necessary to use a section of the graduated meridian whose average scale is the same as the average scale over the distance to be measured. This is a section of the meridian whose mid-latitude is the same as the mid-latitude of the two points between which the distance is being measured. This scale is called the mid-latitude scale. The mid-latitude scale is not exactly equal to the average scale, but it is close enough for practical purposes.

If the total distance can be spanned with the dividers, then merely measure the distance on the graduated meridian by placing the points of the dividers on the meridian at equal distances from the mid-latitude. For a longer distance, set the dividers at some convenient distance such as 100′(100 n.m.), again by placing the points at equal distances from the mid-latitude. Step off the distance, counting the steps. After the last step, reset the dividers at the remaining shorter distance, and read this distance from the graduated meridian at mid-latitude.

The mid-latitude scale is accurate enough if the course does not cover more than about 5° of latitude. If the course does not extend over more than 5° of latitude, divide it into legs and measure the length of each leg with its own mid-latitude scale.

Plotter. The plotter is an instrument for drawing and measuring courses and measuring distances on aeronautical charts. It is made of transparent plastic with lines and scale printed in black. The rectangular part of the plotter has a straight edge for drawing lines





and has scales for measuring distances. The semicircular part of the plotter has two circular scales for measuring directions.

The circular scales are calibrated in degrees. The outer scale, reading from 0° to 180°, is for directions in the first and second quadrants. Since these directions are to the right on the chart, the outer scale has an arrow pointing to the right. The inner scale, reading from 180° to 360°, is for directions in the third and fourth quadrants. Since these directions are to the left, this scale has an arrow pointing to the left. The center of curvature of these scales is marked by a small hole.

The straight edge of the plotter is placed parallel to a line on the chart, with the center hole over a meridian, and the direction of the line is read on the circular scales over the same meridian. The line has two directions 180° apart, one of which is given by each scale. But it must be remembered that a TC has only one direction. Hence, only one scale is read. The arrows on the plotter are an aid in remembering which scale is used. However, each reading should be checked by common sense.

To measure TC, the center hole of the plotter is placed on a meridian while the straight edge of the plotter is parallel with the TC line. This requires a little juggling unless dividers or a ruler is used. If a ruler is laid along the TC line and the plotter is moved against it, the straight edge of the plotter will remain parallel with the TC line while the hole is being centered over the meridian.

The Measurement of True Course. The true course is usually measured by a plotter. However, the compass rose that appears on most charts, or a protractor can be used.

It is important to remember that the meridians are shown differently on different charts. The Mercator projection presents little difficulty in measuring TC since any meridian that is chosen as the north reference line will give the same TC, since all the meridians are parallel. But on the Lambert conformal projection, the meridians converge toward the poles. Therefore, each meridian along a course, when used as the north reference line, will give a different TC. The reason for this is that the line represents a great circle, and we are interested in a rhumb line. The mid-meridian along the course must be chosen as the north reference line, since this will approximate the rhumb-line course.

Preparing a Blank Mercator Chart. Sometimes it is necessary or convenient to draw the TC on a blank Mercator chart. The expanding latitude scale limits the Mercator

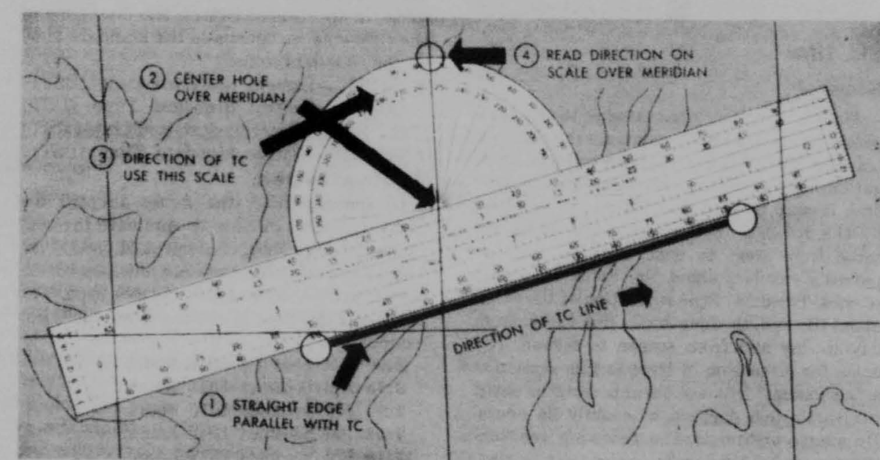
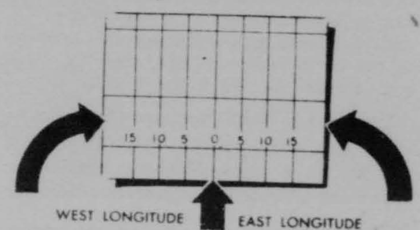


chart to use in those latitudes for which it is constructed. However, a given chart may be used either in north or in south latitude. For north latitudes, turn the chart so that latitude increases from bottom to top; and for south latitudes, turn it so that latitude increases from top to bottom.

A blank Mercator chart may be used for any longitude, east or west. To prepare the chart, meridians are numbered according to the longitudes in which the flight is to be made. For flights in east longitude, the numbers must increase from left to right; and for west longitude, they must increase from right to left. The numbering must be checked to be sure that the numbers increase in the correct direction and that a number has not been skipped or one number written twice.

Use Care in Numbering Meridians



11. TIME

General

Time is of primary importance to the navigator. By its use he can calculate the distance traveled along his course, or in celestial navigation he can calculate his longitude. In general, it may be said that time is determined by the rotation of the earth. The earth rotates from west to east and the sun apparently revolves about the earth from east to west. Because of the revolution of the earth about the sun, the length of a day varies from day to day and from season to season. The basis for discussion of time in this section is a **"mean sun,"** which apparently rotates about the earth, 360 degrees, in exactly 24 hours. By simple arithmetic the following relationships may be developed:

In one hour, the sun travels 15° of longitude.

In four minutes, the sun travels 1° of longitude.

In one minute the sun travels 15′ of longitude.

It is not difficult to reason that time differs at every meridian on the earth's surface. When the sun is over the meridian of New York City, it is noon at New York City. At Boston, it is past noon, and at Washington, D.C., it is before noon. The time of places east of us is later, while the time of places to the west of us must be earlier.

Much confusion would result if each place on the earth kept its own time. For convenience the world has been divided into 24 time zones of approximately 15° longitude in width. Each time zone carries the time of the central meridian in that zone.

Kinds of Time

Mean or Civil Time is based on the travel of the mean sun about the earth. At the same instant, points of different longitude never have the same civil time.

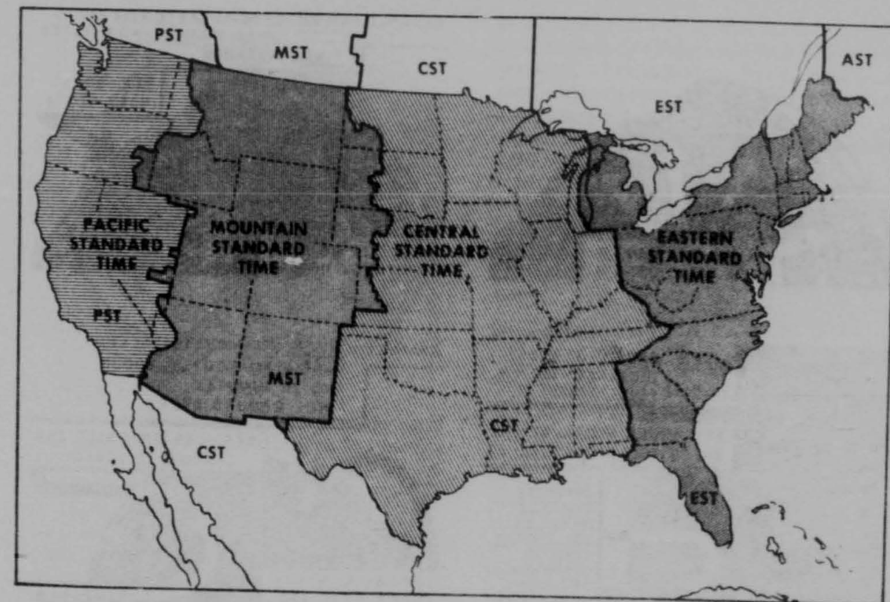
Standard or Zone Time is the time kept by watches. It is based on the civil time of a selected meridian within the time zone. Standard time zones are not all exactly 15° longitude in width. The boundaries of standard time zones are bent so they will not pass through principal cities and railway junctions. In the United States, the civil time of the following meridians is the standard time of the standard zones:

(1) 75°—Eastern Standard Time (EST)
(2) 90°—Central Standard Time (CST)
(3) 105°—Mountain Standard Time (MST)
(4) 120°—Pacific Standard Time (PST)

24-Hour System

During the War, the Army adopted the 24-hour system of time to eliminate the confusion in the abbreviations A.M. and P.M. The values of A.M. time are unchanged except that four figures are always used. The value of P.M. time is increased by 1200. For example:

8:00 AM becomes 0800 hours
3:15 AM becomes 0315 hours
1:15 PM becomes 1315 hours
7:42 PM becomes 1942 hours
11:19 PM becomes 2319 hours



Hack Watch

A navigator needs an accurate watch which has a synchronized second hand. For most of his purposes he needs to know the time accurately to the half minute, but in celestial navigation he should know the time within two or three seconds. The Air Force has developed a watch especially for this purpose (type A-11).

12. TIME, SPEED AND DISTANCE

General

The most important and fundamental problems of navigation are those involving the familiar formula of time, speed and distance. Distance in navigation is expressed in nautical miles or statute miles. The units of time used in navigation are the familiar hours, minutes, and seconds. Speed is rate of motion, or the distance traveled per unit time. Thus, it is a ratio between distance flown and time of flight. The units of speed used in navigation are statute miles per hour, which are called simply miles per hour (mph) and nautical miles per hour, which are called knots (K). Knots mean nautical miles per hour.

So long as the speed of an airplane remains the same, the distance flown increases in the same ratio as the time. Given the ratio (speed), the distance flown in a certain time or the time to fly a certain distance can be found. Or, given the distance and time, the ratio (speed) can be found. The proportion can be transformed into three formulas:

$$\text{Distance} = \text{Speed} \times \text{Time}$$

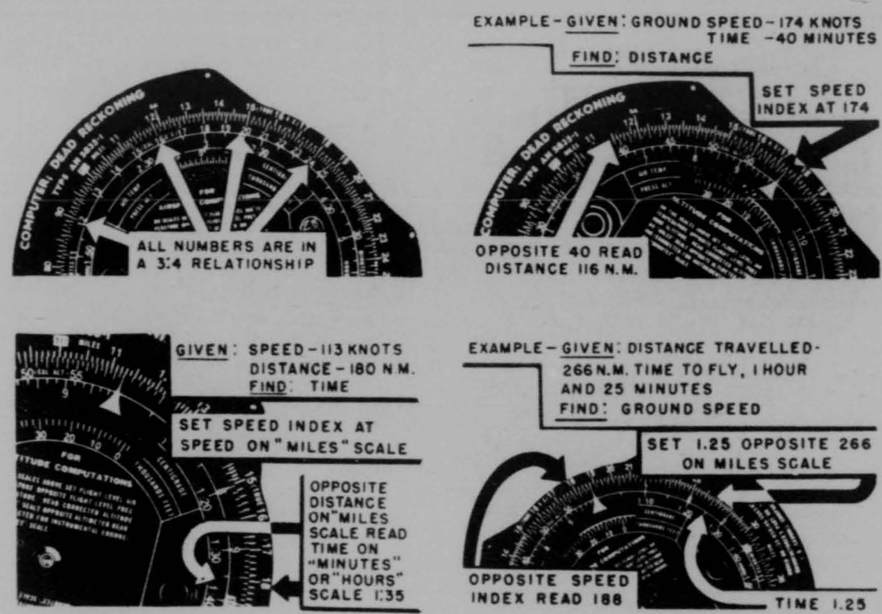
$$\text{Time} = \frac{\text{Speed}}{\text{Distance}}$$

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

In using these formulas, remember that units must be consistent throughout. Thus if speed is in miles per hour, time must be in hours, not minutes. And if distance is in nautical miles, speed must be in knots, not in miles per hour.

The E-6B Computer

The Air Force has developed a special computer to solve air navigation problems called the E-6B Computer. It is affectionately known as the "wife" of the navigator.



Simple Proportion. The slide-rule face of the E-6B is so constructed that any relationship between two numbers, one on the stationary scale and one on the movable scale, will hold true for all other numbers on the two scales. If the two 10's are placed opposite each other, all other numbers will be identical around the whole circle. If 20 on the inner scale is placed opposite 10 on the outer scale, all numbers on the inner scale will be double those on the outer scale. If 12 on the outer scale is placed opposite 16 on the inner scale, all numbers will be in a three-to-four relationship. This feature of the slide rule permits one to supply the fourth term of any mathematical problem in proportion. The simplest and most useful application of this feature of the computer is in the solution of time-speed-distance problems.

13. THE MAGNETIC COMPASS

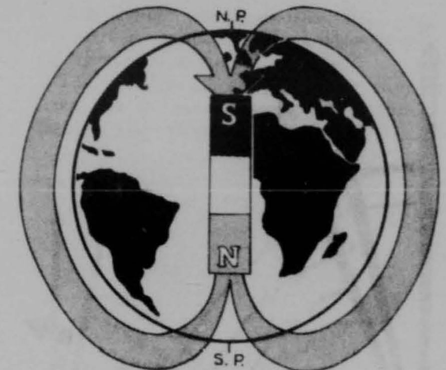
General

Orientation to direction comes almost automatically on the ground for most people because they are always near familiar landmarks. But the airman would become hopelessly lost in a short time in the air without some mechanical means of orientation as to direction. This mechanical means of orientation to direction is provided by the magnetic compass, the gyro indicator, the astrocompass, and the radio compass. Of these, only the magnetic compass is north-seeking.

Earth's Magnetism and the Compass

Since a freely suspended magnet everywhere on the earth always tends to assume a certain direction relative to the earth, it is clear that the earth itself acts as a magnet. The magnetic poles of the earth do not coincide with the geographic poles. The north magnetic pole is on the Bothia Peninsula, northwest of Hudson Bay, at about 71°N, 96°W; and the south magnetic pole is in Antarctica at about 73°S, 156°E.

If the whole earth were a magnet, one would expect a tremendous force of attraction and repulsion to occur at the so-called magnetic poles of the earth. Actually, attrac-



EARTH'S MAGNETIC FIELD

tion and repulsion at these poles is somewhat less than at some other points on the earth's surface. It is as if the earth's magnetic field is due to a short stubby magnet at the center of the earth.

A magnetized needle, free to rotate on a horizontal plane, is a magnetic compass in its simplest form. If the north-seeking pole is differentiated from the south-seeking pole, say by blue paint, the needle will serve as a crude direction finder. From most points on the earth, the needle will point in the general direction of the north magnetic pole; but it doesn't necessarily point directly toward it. Actually, the needle indicates the direction of the earth's magnetic field. Since the north and south magnetic poles are not directly opposite, it is impossible at most places on the earth for one end of the needle to point to one magnetic pole while the other end points to the other.

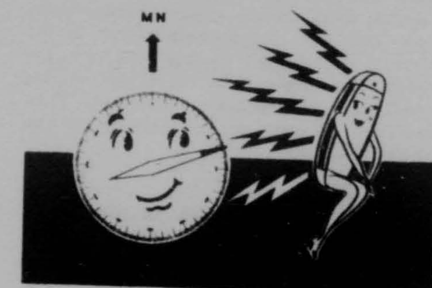
Variation

When a compass needle is influenced only by the earth's magnetic field, the direction in which it points is called the **magnetic north.** In contradistinction, the direction of the north geographic pole may be called **true north,** though usually it is called simply north. Just as true directions are measured from true north, so magnetic directions may be measured from magnetic north. **The angle between magnetic north and true north is variation.** Thus variation is the angle between the meridian and the needle of a compass influenced only by the earth's magnetism. Variation differs at different points on the earth. If the needle points to true north, then magnetic north and true north coincide; and variation is zero. If the needle points east of north, variation is east; and if it points west of north, variation is west.

In the area about either magnetic pole, variation ranges through a complete circle. Thus, north of the north magnetic pole and south of the south magnetic pole there are places where the variation is a maximum of 180°.

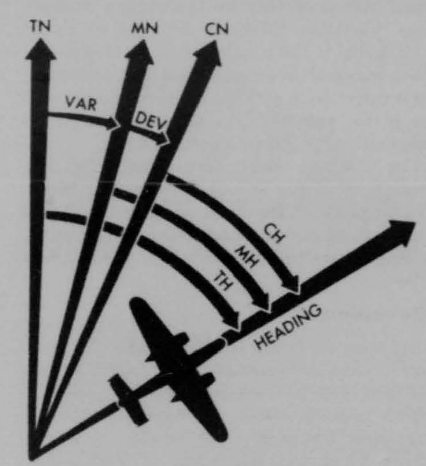
Deviation

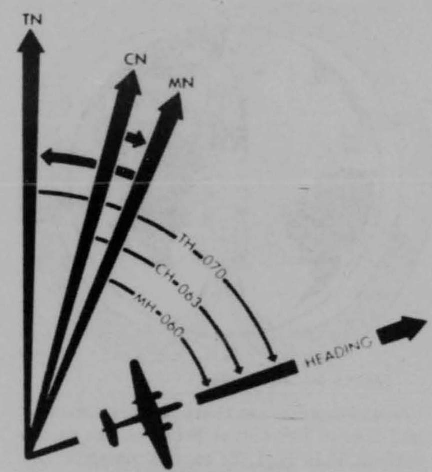
A compass needle is affected by other magnetic fields besides that of the earth. A piece of iron close to the needle tends to deflect it from magnetic north. A magnetic field is set up about a wire in which an electric current flows. Thus electrical equipment near a compass also can deflect the needle. Since an airplane has both iron and electrical equipment, the needle of an aircraft compass often is deflected from magnetic north.



The direction in which a compass needle points is called **compass north.** Compass directions may be expressed relative to compass north just as true directions are expressed relative to true north and magnetic directions are expressed relative to magnetic north.

The angle between magnetic north and compass north is deviation. Thus deviation is the angle between the compass needle and the direction the needle would point if it were affected by no magnetic influences other than that of the earth. If the needle is deflected to the east of magnetic north, devia-





tion is east; if to the west, deviation is west.

If an airplane changes heading, the compass needle continues to point in about the same direction while the airplane turns with relation to it. As the airplane turns, therefore, iron and electrical equipment in the airplane change their position relative to the needle. Hence their influence on the compass needle changes and deviation changes. Thus deviation depends on the heading of the airplane.

Heading

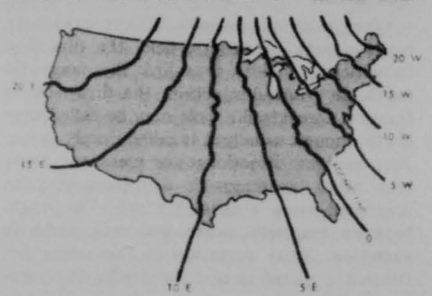
The direction in which an airplane is pointed is its heading. This direction may be expressed with relation to true north, magnetic north, or compass north. Heading measured with relation to true north is **true heading (TH).** Thus TH is the angle measured from true north clockwise to the forward end of the airplane's longitudinal axis. Likewise, heading measured with relation to magnetic north is **magnetic heading (MH)**. And heading measured relative to compass north is **compass heading (CH)**.

The compass rose of magnetic directions is turned with respect to the compass rose of true directions by the amount of variation. Thus TH always differs from MH by the amount of variation. If variation is east, TH is greater; if variation is west, it is less. Likewise, MH always differs from CH by the amount of deviation. If deviation is east, MH is greater; if deviation is west, MH is less.

It must be remembered that heading is the same direction with relation to the earth, whether it is expressed as TH, MH or CH.

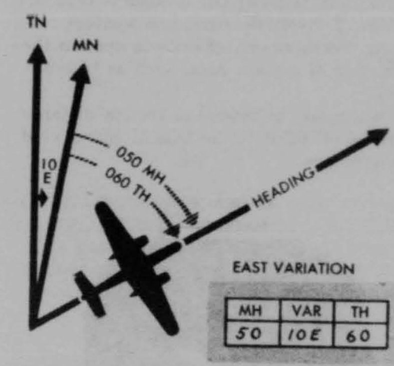
Finding Variation and Deviation

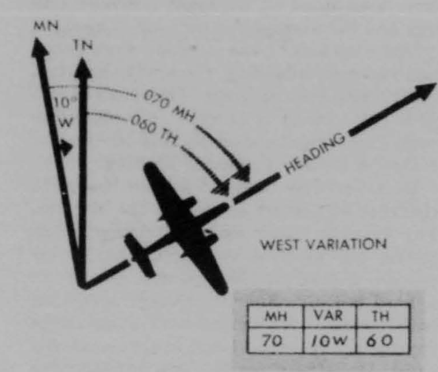
The variation for different points on the earth is fairly well-known. Variation is shown on aeronautical charts by means of lines connecting points of equal variation. Such a line is an **isogonic line.** The isogonic line labeled 10°E passes through all points on the chart where the variation is 10°E. Note that the compass needle will not necessarily be parallel with the isogonic line. An isogonic line for 0° variation is called an **agonic line.** In certain areas, variation is very erratic. Sometimes it varies as much as 80° in less than

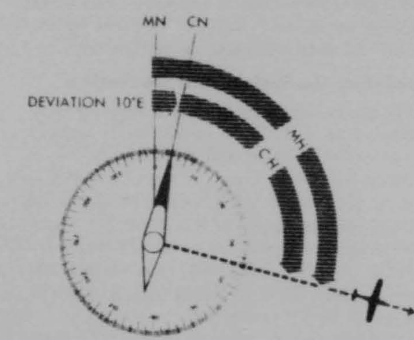


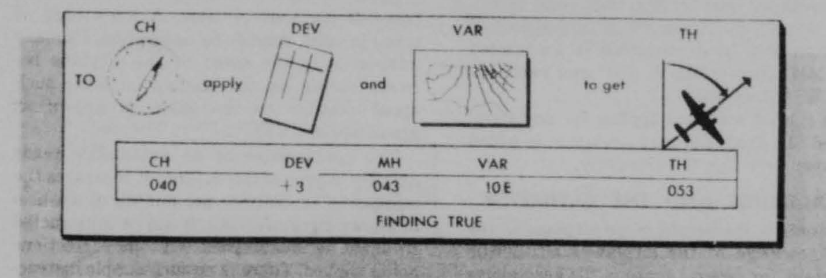
a mile, though this is unusual. Such areas are marked on charts. The variation is more nearly normal at higher altitudes.

The variation at any one point changes from year to year in a somewhat rhythmical fashion. The extremes of the change may exceed 50° over a long period. The year for which the isogonic lines are drawn is indicated on aeronautical charts. Sometimes the annual change also is indicated. Usually, however, the aeronautical chart is obsolete for other reasons long before the change in vari-









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ation is great enough to cause difficulty.

Usually variation offers no problem. It is simply read from the chart. If variation changes only 2° or 3° in the length of a flight, the average of the variation at departure and that at destination is used. If the change is more than about 4°, the flight is divided into legs and the average for each leg is used.

Deviation is not quite so simple since deviation varies with heading. Generally, deviation is determined for headings of intervals of 15°. This information is entered on a deviation card. The navigator consults this card for the deviation for any particular heading.

Deviation may change with any change in electrical equipment or iron in the airplane. For example, deviation may change when bombs are dropped or ammunition is expended. It may even change with the jolt of a hard landing. And, it changes somewhat with latitude. The deviation card should be approximately correct but it is not necessarily exact. Deviation from the card is used when no better information is available; but when possible, deviation is checked in flight by the use of the astro-compass or driftmeter.

Applying Variation and Deviation

TH can be found by applying deviation and variation to CH. This operation is simply a matter of addition and subtraction.

When variation is east, magnetic north is east of true north. MH, measured clockwise from magnetic north, is less than TH measured clockwise from true north. Therefore in order to find TH from MH, east variation is added to MH. Thus if MH is 050° and variation is 10°E, TH is 060°.

Similarly, when variation is west, magnetic north is west of true north and MH is larger than TH. Therefore, in order to find TH from MH, west variation is subtracted from MH. Thus if MH is 070° and variation is 10°W, TH is 060°.

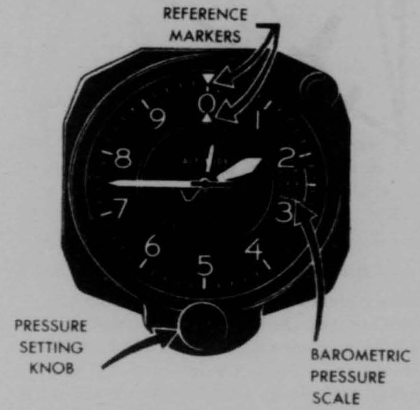
The rule of variation applies for deviation. To find MH from CH east deviation is added and west deviation is subtracted.

14. ALTITUDE AND THE ALTIMETER

Altitude is the height of an airplane in the air. Knowledge of the airplane's altitude is important for several reasons. To keep above dangerous mountain peaks, one must know the altitude of the airplane and the elevation of the surrounding terrain at all times. This is especially important when visibility is poor and one must fly high enough to clear the highest terrain or obstructions in the area one estimates himself to be.

Often a certain altitude is flown to take advantage of favorable winds and weather conditions. Furthermore, altitude is used in the calculation of certain data, such as true airspeed.

Altitude may be defined as vertical distance above some point or horizontal plane used as a reference.

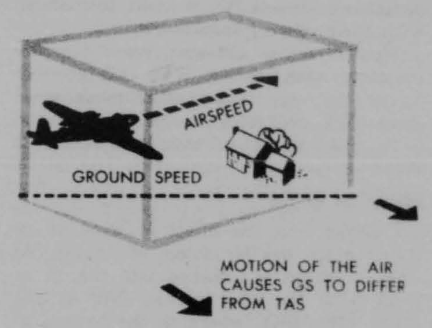


15. AIRSPEED AND THE AIRSPEED INDICATOR

General

Speed is rate of motion or the distance traveled per unit of time. A knowledge of speed is indispensable to navigation. Primary interest is in the speed of the airplane between points on the earth's surface; such speed relative to the earth is known as **groundspeed (GS).**

The speedometer of an automobile reads directly in groundspeed. Since it measures the number of revolutions per minute of a wheel of known circumference, it can be constructed to show accurate speed without corrections being applied. There is no such simple instrument to give the groundspeed of an airplane



directly. Groundspeed may be found in various ways, but each way involves calculations.

It is possible to measure by instruments the speed of an airplane through the air. This is known as **true airspeed (TAS).** If the air were still with relation to the earth, groundspeed would equal TAS. But, the air is almost constantly in motion. This motion of the air relative to the earth is called wind. If the airplane flies with the wind, groundspeed is greater than TAS; if it flies against the wind, groundspeed is less than TAS. However if the wind, the TAS, and the true heading are known, the GS can be found.

The Airspeed Indicator

The instrument which measures airspeed is an **airspeed indicator.**

Computing True Airspeed

The reading of the airspeed indicator depends not only on the TAS of the airplane but also on the density of the air through which the airplane is flying. Pressure difference increases with TAS. If density is twice as great, there are twice as many particles of air in a given volume. At the same TAS, therefore, an airplane collides with twice as many particles of air, and the pressure difference increases. Since the airspeed indicator measures pressure difference, its reading increases with density of air as well as with TAS.

The airspeed indicator is designed to read TAS under standard sea-level conditions, that is when pressure is 29.92" and temperature is 15°C. Air density decreases with altitude;

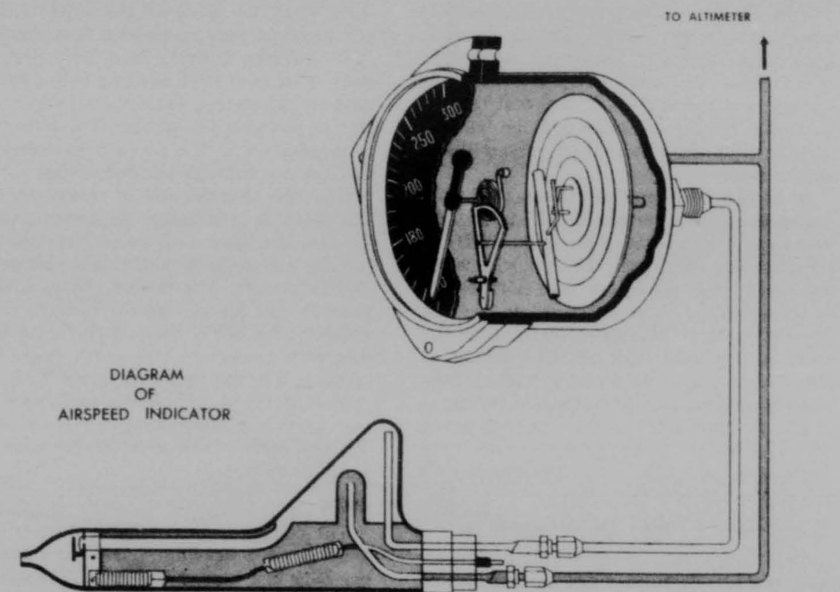


DIAGRAM OF AIRSPEED INDICATOR

therefore at higher altitudes the airplane has to fly faster to cause the same pressure difference. Thus for a given TAS, IAS decreases with altitude. Or to put it another way, for a given IAS, TAS increases with altitude.

IAS is corrected for temperature and pressure by means of the airspeed correction scale on the E-6B computer. This scale is opposite the altitude correction scale. In the window is a scale of pressure altitude readings from approximately —1,000 ft. to +34,000 ft. Above it is an air temperature scale reading from approximately —50° to +50°.

16. WIND AND DRIFT

General

If the air in which airplanes fly were absolutely still, aerial navigation would be very simple. In fact there would be little need for a specially-trained navigator, and this chapter would not be necessary. The pilot, merely by correcting for variation and deviation, easily could set the airplane on any desired course. He could calculate estimated times of arrival and determine positions en route by using the true airspeed.

Unfortunately, however, this situation seldom, if ever, exists. Wind makes the air navigator and his costly equipment necessary. It has been said that navigation is wind-finding; and this statement is almost true. A navigator must continually find the wind if he is to obtain the results required in military air operations.

Wind is a horizontal movement of the air across the earth's surface. Wind has both direction and speed. **Wind direction (WD)** is the direction from which the wind is blowing, measured with respect to true north. Like other directions it is expressed in degrees from 0° to 360°. Thus, if a wind is from the west, it is a west wind and its direction is 270°. Note that wind direction differs from other directions used in navigation in that it is the direction from which, rather than the direction toward which, motion occurs. True heading, for example, is the direction toward which the airplane is headed.

Wind Speed (WS) Or Wind Force

This is the rate of movement of the air over the earth's surface. Meteorologists and navigators express WS in knots to conform with their other measurements.

Wind direction and wind speed together constitute **wind velocity (WV).** It is incorrect to use the word "velocity" to mean speed alone. "WV, 180°/25K" means that the wind is from the south and that its speed is 25 knots.

Effect of Wind

Consider first the effect of wind on an object which has no motion of its own. At 0900 a balloon is launched into the air at point A. If the wind is from 270° at 20K (WV, 270°/20K), where is the balloon at 1000? The balloon may be thought of as floating in a body of air which moves from 270° to 90° at 20K. In one hour the body of air moves 20 n.m., and the balloon with it. Thus at 1000 the balloon is at point B, 20 n.m. from point A in a direction of 90°. A balloonist never feels any wind. He is suspended in the body of air and moves with it. No air moves past him. A balloon in the air is just like an empty bottle floating down a river.

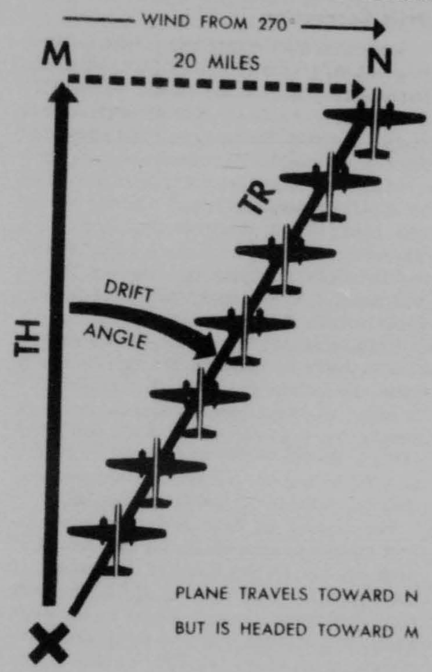
Any free object in the air moves downwind with the speed of the wind. This is just as true of an airplane as it is of a balloon. If an airplane is flying in a 20K wind, the body of air in which it is flying moves 20 n.m. an hour. Therefore, the airplane also moves 20 n.m. downward in an hour. This movement is in addition to the forward movement of the airplane through the body of air.

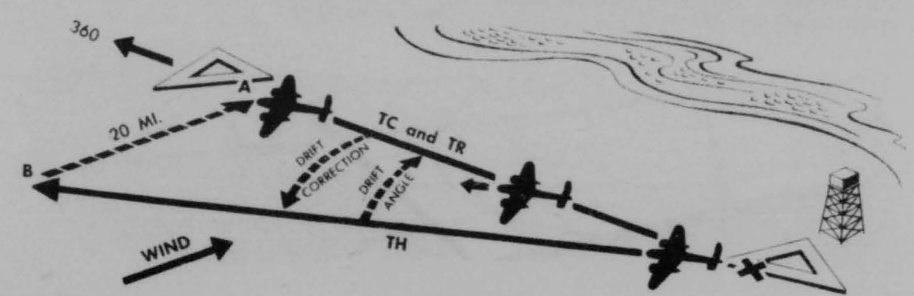
It is clear that the path of an airplane over the earth is determined by two unrelated factors: the motion of the airplane through the air, and the motion of this air across the earth's surface. The motion of the airplane through the air is directly forward in response to the pull of the propellers; its direction with respect to true north is the true heading, TH and its speed is the TAS. The motion of the air across the earth's surface may be in any direction with respect to the TH; its direction and speed of course are the wind velocity.

Drift

The plane in the next figure departs from point X on a heading of 360° and flies for one hour in a wind of 270°/20K. The airplane is headed toward point M, directly north of X, so its TH is represented by the line XM. If there were no wind, the airplane would be at point M at the end of the hour. However, there is wind. The body of air in which the airplane is flying moves 20 n.m. in the hour and the airplane moves with it. Consequently, at the end of the hour the airplane is at point N, 20 n.m. downwind from M. Thus, the line XM is the path of the airplane through the body of air; the line MN shows the motion of the body of air; and the line XN is the actual path of the airplane over the earth. The actual path of the airplane is the **track (TR).** Track should be distinguished from true course (TC) which is the intended path of the airplane.

The sideward displacement of the airplane by the wind is called drift. Drift is measured





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by the angle between TH and TR; this is the drift angle. In the example, the drift angle is MXN, the angle betwen the heading XM and the track XN. The plane has drifted to the right; this is known as right drift.

A given wind causes a different drift on each different heading. It also affects the distance traveled in a given time. Therefore, with a given wind the GS varies on different headings.

Drift Correction

Suppose a pilot wants to fly from point X to point A, a true course of 360°, when the wind is 270°/20K. What should be the TH? Obviously, if he flies a TH of 360°, he will end up, not at A, but at some point downwind from A. Rather, he must head for some point upwind from A and let right drift bring him to A. If the airplane is to be in the air for one hour, it will drift 20 n.m. downwind. Therefore, he must head for a point 20 n.m. upwind from A. Flying the heading XB, he will reach A in one hour; the TR of the airplane will be XA.

Heading an airplane upwind from destination in order to maintain the true course is called correcting for drift. The angle AXB is called the drift correction angle or, more simply, the drift correction. **Drift correction (DC)** is the correction which must be applied to a TC to find the TH needed to make good that TC. AXB is a left drift correction.

The amount of drift correction must be just enough to compensate for the amount of drift on the correct heading. Therefore, if the airplane is on a heading of XB, the drift correction angle must be equal to the drift angle. But, if drift is to the right, drift correction must be to the left. Therefore the drift correction angle is measured in the opposite direction to the drift.

Remember that after a navigator has corrected for drift, the airplane will still drift. All he has done is to head the airplane off course so that the wind will cause it to drift back on course. Changing the heading of the airplane will not turn off the wind.

Drift correction is usually found in the air by one of the following methods:

a) Reading the drift correction directly from the driftmeter. The disadvantages of the driftmeter are that the ground must be visible and that accurate drift is difficult to obtain if the airplane is 9,000 ft. above the terrain or over 4,000 ft. above the water, or if the water is smooth.

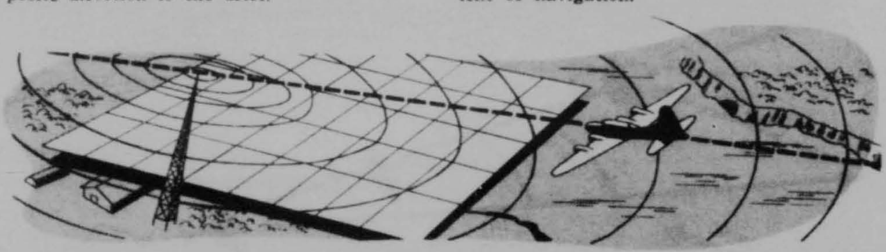
b) The drift correction usually is found by solving the wind triangle, which will be discussed later.

17. DEAD RECKONING AND AIDS TO DEAD RECKONING

Precision Dead Reckoning

The navigator has three basic problems: locating his position at any time, calculating the time at which he will reach any point, and calculating a TH to bring the airplane to any desired destination.

Dead reckoning is the method of solving these three problems by means of measurements and calculations involving time, a known position, and one or more of the three velocities: TR-GS, TH-TAS, and WD-WS. These calculations are made with the time-speed-distance formula and the wind triangle. Dead reckoning is the navigator's basic method because it is the only means of solving all three of these basic navigational problems. In a sense, then, dead reckoning is the equivalent of navigation.



Location of Position

There are three methods of locating position during flight. One depends on external means, and the other two are forms of dead reckoning.

Fixes. By map reading, radio or celestial means, the navigator can locate the position of the airplane without the use of dead reckoning. When he finds on a chart the position of a landmark which is directly beneath the airplane, he has located his position by map reading. Similarly, by radio and celestial, he locates position by external means. This is called fixing the airplane's position; and the position he finds is a fix.

Basic Dead Reckoning. If the location of the departure point is known, the time of departure, the TR and GS of the airplane, and the position of the airplane for any time can be found. The departure point is plotted on a chart. Subtracting the time of departure from the time of the desired position, the time on course can be found. By means of the time-speed-distance formula, the distance flown in this time at the known GS can be found. From the departure point on the chart, this distance is laid off in the direction of the known TR. Thus, the desired position is established. This is a dead reckoning position or **DR position** as distinguished from a fix.

This process is perhaps the most fundamental application of the dead-reckoning method. Therefore, it is often called basic dead reckoning. Thus, in basic dead reckoning, known position, the elapsed time, and the TR-GS vector are known. The wind is not known.

Precision Dead Reckoning. If the location of the departure point, the time of departure, the TH and TAS of the airplane, and the wind velocity are known, the position of the airplane for any time can be found.

Calculation of Time of Arrival

There is only one method of finding the time at which an airplane will reach any given point. A navigator must know the time of departure from some position, the distance to the given point, and the GS which the airplane wil make on the TC to the point. By means of the time-speed-distance formula, he can find the time required to fly this distance at this GS. He adds this time to the time of departure in order to find the time of arrival at the given point.

Dead Reckoning

The methods described are the only methods of solving the three basic navigational problems. Because the second and third problems can be solved only by dead reckoning, dead reckoning is essential to navigation. Map reading, radio, and celestial observation can solve only the problem of location; they cannot solve the other two. Therefore, they are not distinct methods of navigation comparable to dead reckoning. However, by solving the problem of location, they give information which helps to solve the other two problems. Thus, they are a source of dead-reckoning data. Therefore, map reading, radio and celestial are called aids to dead reckoning.

Precision dead reckoning is the only single method of solving all three of the basic problems. Basic dead reckoning will solve only the first and second problems, and it will solve these only under special conditions. Because precision dead reckoning is the only complete method, precision dead reckoning is carried on continuously during flight.

Procedure of Precision Dead Reckoning

Precision dead-reckoning procedure involves more than the mathematical solution of the three basic navigational problems. It includes also the procedure by which the navigator plans his work and continually sets these problems for himself; it includes much of the method by which he obtains the information necessary for their solution. He obtains this information from two sources: the flight instruments—the compass, airspeed indicator, driftmeter, clock, free air temperature gauge, and altimeter—and the aids to dead reckoning. Thus, precision dead reckoning includes the reading of the instruments. It also includes the determination of wind, TR, and GS from the fixes given by the aids to dead reckoning; but it does not include the actual use of the aids to obtain these fixes. Thus, precision dead-reckoning procedure involves practically all the navigational activities except the calibration of instruments and the actual use of map reading, radio and celestial.

If the navigator can read drift, he can do precision dead reckoning by the flight instruments alone. However, if the ground is obscured so that he cannot read drift, he must rely on one of the aids to dead reckoning for information both as to his position and as to the wind. Moreover, even when he can read drift, the establishment of positions by instrument dead reckoning alone is subject to small errors. As he travels farther from a known position, these errors may accumulate into large errors. Hence, in order to correct his dead reckoning, he must establish definitely his position from time to time by one of the aids.

18. MAP READING

General

Map reading is the identification of landmarks with their representations on a chart. Map reading can be the most accurate of the aids to dead reckoning. The accuracy of a celestial or radio fix is usually in doubt; but when an object on the ground has been identified on an accurate chart the exact location of the plane is known. The aeronautical charts which are used in the United States are relatively accurate and complete; but in other parts of the world accurate information is not available. Obviously map reading cannot be more accurate than the charts being used.

19. OTHER AIDS TO DEAD RECKONING

The Automatic Radio Compass

For the navigator, the principal value of the automatic radio compass is its ability to give a continuous and automatic bearing on any radio station within the frequency and sensitivity of the radio set that is in the airplane. When the radio set is properly tuned and adjusted, the azimuth indicator (radio compass pointer) points toward the station. This property of the radio compass is used in two ways: for homing and for radio fixes.

Homing. If the heading of the airplane is adjusted so that the azimuth pointer always points to the triangular index the airplane will be headed approximately toward the radio station. The relative bearing between the airplane and the radio station is then zero. When the pointer swings 180° the airplane is passing over the radio station. This is the most common use of the radio compass.

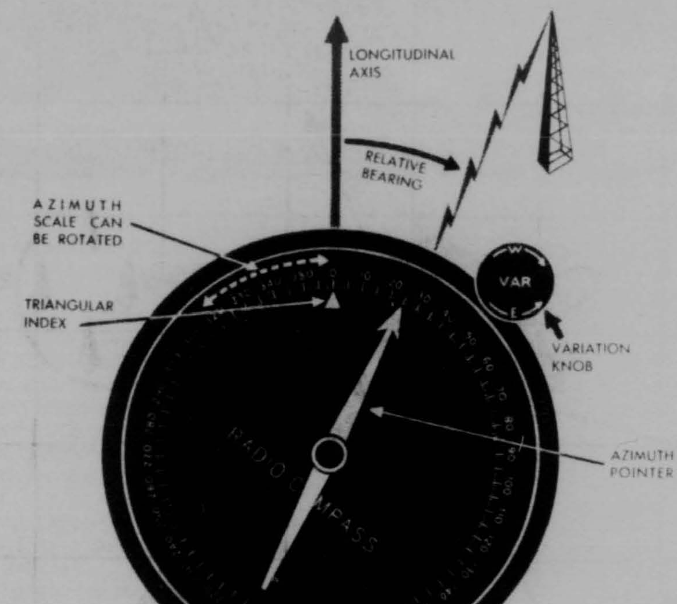
Radio Fixes. Since the azimuth pointer points toward the radio station, the number of degrees that the pointer differs from the longitudinal axis of the airplane can be determined by reading the radio compass. This is known as a **relative bearing (RB).** If this relative bearing is added to the true heading of the airplane, the **true bearing** (angular distance from true north) of the airplane from the station can be found. This is done mechanically by setting the true heading at the triangular index by rotating the azimuth scale with the variation knob. To the true bearing, 180° is added to get the true bearing of the radio station from the plane since the radio station's position is known. This can be accomplished mechanically by simply reading the azimuth scale at the tail of the pointer. Now if this true bearing is plotted from the radio staion, the position of the airplane will be on the line drawn **(LOP): line of position.** If this procedure is repeated for another radio station and its true bearing drawn, the two lines will intersect showing the approximate position of the airplane. This is known as a radio fix.

Celestial Navigation

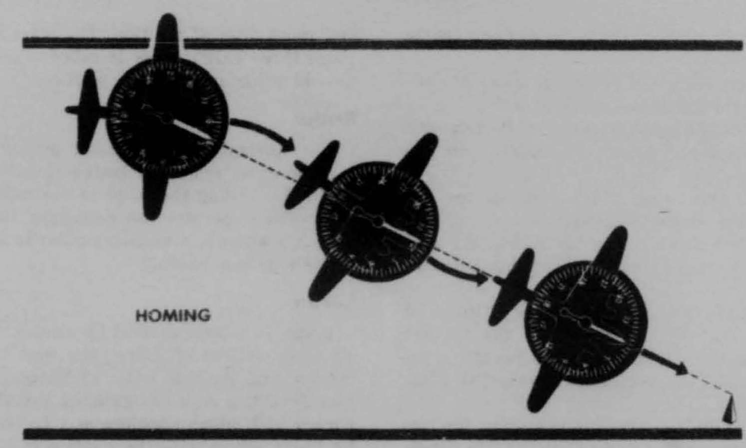
Celestial navigation is the employment of celestial bodies—the stars, sun, planets and the moon—to determine position. The Egyptians used celestial navigation prior to 2000 B.C. This means navigation was used on the Mediterranean by the Greeks, Phoenicians, Carthaginians and later the Romans.

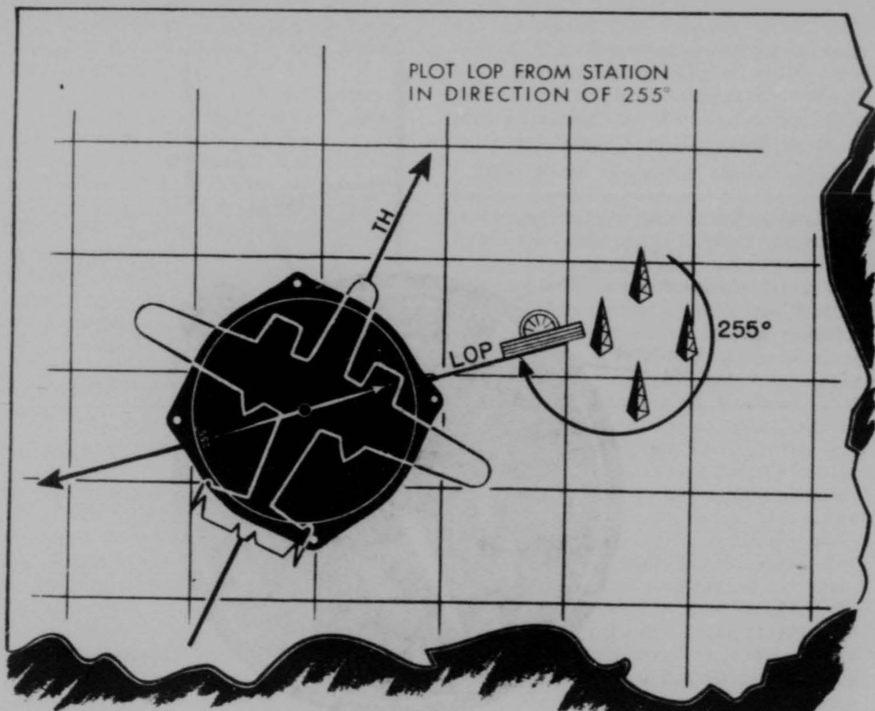
Very briefly, here is an explanation as to to how a navigator finds his position of the earth by celestial means.

Astronomers and mathematicians have made a set of tables from which the altitude or angular distance above the horizon of any visible celestial body can be found for any particular moment in the day for any position on the earth. The navigator has a sextant, more correctly called an "octant," which is an optical instrument for the determination



AZIMUTH INDICATOR





of the altitude above the horizon of any visible celestial body.

The navigator can determine a line of position from Polaris, the North Star, by:

a) Making an observation of Polaris with his sextant and noting the time of the observation.

b) Determining a DR position for the same time as the observation.

c) Consulting his tables to find the altitude of Polaris for this time at this DR position.

d) Then by comparing the altitude of Polaris that he obtained from the sextant with the altitude of Polaris he found for his DR position, the navigator can establish a line of position.

Now if he repeats this operation for two more stars, Altair and Deneb, he will obtain two more lines of position. The place where these three LOP's cross is called a celestial fix and is his approximate position.

Radar

The navigator is interested primarily in the radar set made for installations in aircraft. By reading the scope of the radar set, the trained operator can determine the airplane's position in a manner similar to finding position by map reading.

Loran

Loran is a term derived by combining the first two letters of LOng, the first two of RAnge, and the first letter of Navigation. It was developed as a navigational aid. The accuracy with which positions may be obtained by Loran varies with the location of the air-

craft relative to ground stations, and with other conditions of transmission and reception.

The effective range of Loran over sea water is about 600 to 700 nautical miles in the daytime, and 1200 to 1400 at night. This great range is achieved by the use of relatively low radio frequencies, just above the standard broadcasting band, which can propagate over the curvature of the earth.

Briefly, here are the principles of Loran operation:

a) Radio signals consisting of short pulses are broadcast from a pair of ground-based transmitting stations.

b) These signals are received on a specially-designed Loran radio receiver located in the aircraft.

c) The difference in time of arrival of the signals from the two radio stations is measured on the Loran indicator.

d) This measured time difference is utilized to determine directly from Loran charts a line of position on the earth's surface.

e) Two lines of position, determined from two pairs of transmitting stations, are crossed to secure a Loran fix.

Thus, Loran is entirely different from radio direction-finding, for Loran measures the time of arrival of radio waves, rather than the direction of arrival.

Loran is different from radar in that there is no transmission from the aircraft. Loran has, however, borrowed from radar some of the radar techniques for measuring time to millionths of a second, and techniques for visually observing signals on a cathode ray tube.

20. FEDERAL AIDS TO NAVIGATION

Introduction

Government-established and maintained airways in the United States, as well as in

other countries, are of great help to the pilot and navigator. In effect, the airways are air highways. They form a network linking all important points in the country. They reduce problems of navigation to standardized methods which work at any time and place and in all weather conditions. Traveling on the airways, a pilot can go virtually anywhere in this country, and at no time will he be more than fifty miles from an airport. In thinly-populated areas, where there otherwise would be no airports, the Government maintains intermediate landing fields at intervals of about fifty miles along the airways.

Besides the landing fields, airway aids include radio range stations, rotating beacon lights, radio marker beacons, and weather information.

Radio and lighting aids are marked in red or purple on sectionals and regionals, and other charts showing aeronautical data. The symbols for these aids are shown in paragraph 4e of section V, chapter 00.

Radio Range Stations

Radio range stations in the United States are spaced at intervals along all airways and are located near important airports. The distance between the ranges and the power output of the stations usually make it possible to receive several nearby ranges from any point along the airways.

At least two of the on-course legs of a range station are directed along the center line of the airway, one in each direction. This provides directional guidance on the airway both in approaching and departing from the range station. An airplane equipped with any receiver which can be tuned to range frequencies (200-410 kc) can follow the airways without sight of the ground.

Rotating Beacon Lights

The airways are marked at night by rotating beacon lights, which are spaced at intervals of approximately ten miles. Seen from the air, the beacons form an on-course light line visible from twenty to forty miles. Aeronautical charts indicate each beacon by a star with an open center, and arrows with this symbol indicate the beacon has course lights and show the direction of the light line.

The location of a beacon on an airway is flashed in an identifying code letter which shows its distance from the origin of the airway. Beacons are numbered from west to east and from south to north between terminal cities. The number of the beacon, multiplied by ten, gives its approximate distance in miles from the origin of the airway. For example, beacon No. 1 is ten miles from the origin of the airway, and beacon No. 5 is fifty miles.

The beacon number is identified by a letter flashed in International Morse code. The first letter of each word in the following sentence corresponds to the number given with it:

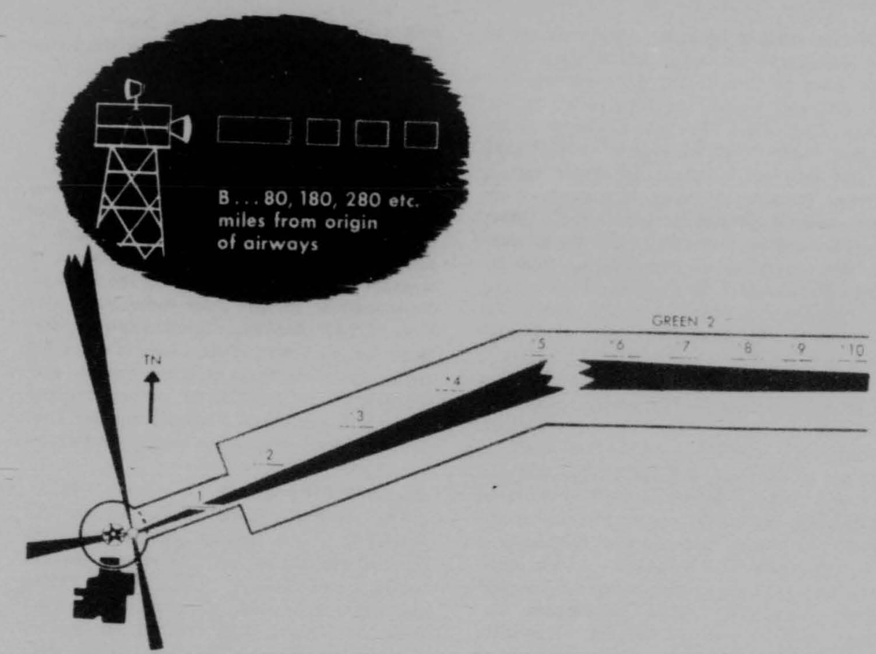
(1) When (2) Undertaking (3) Very (4) Hard (5) Routes (6) Keep (7) Directions (8) By (9) Good (10) Methods.

Because only ten letters are used, it is necessary that the same letters represent beacon numbers of beacons that are more than 100 miles from the origin of the airway. The number of a beacon more than 100 miles and less than 1,000 miles from the origin of an airway is a two-digit number; the code letter flashed by the beacon represents only the last digit. Thus "W" is the code letter for beacons numbered 1, 11 and 21, which are respectively 10 miles, 110 miles and 210 miles from the origin. Likewise, "U" is the code letter for beacons numbered 2, 12, 22, etc. Thus the series of code letters is repeated for each 100-mile section of the airway; this presents no problem because the navigator should know which 100-mile section of the airway he is on.

Airway beacons show six clear flashes per minute. The identifying code letter, displayed between flashes, is visible only to airplanes on course. The letter is flashed in green if the beacon is located at an airport; if not, it is flashed in red. The number of the beacon, as well as the corresponding code signal, is printed beside the beacon symbol on aeronautical charts. The number also is painted on the roof of the beacon power shed for daytime identification.

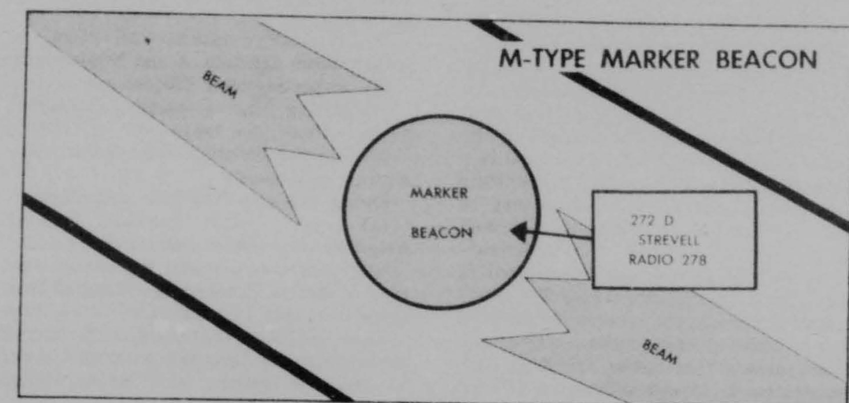
Radio Marker Beacons

The main purpose of marker beacons is to assist the navigator or pilot in obtaining fixes at the range station and along the airways at intermediate points between range stations. The principal types of marker are the



M-, Z- and fan-types.

M-Type Marker Beacon. This type of beacon is a low-powered, non-directional radio station which transmits a characteristic signal, such as "R" (dot-dash-dot), once every few seconds. It is usually equipped for voice communication with aircraft. Its range is from three to ten miles, depending on the weather and the type and condition of the receiver.



M-type marker beacons, usually placed at the intersection of two range courses, indicate when to tune to the next station. The characteristic signals are transmitted on the same frequencies as the adjacent radio ranges; thus the marker signals can be heard if the receiver is tuned to either range. Marker beacons also may be placed on or near some obstruction, such as a radio tower or at some particular point along the airway. The M-type beacon does not operate continuously. It is turned on when the local ceiling is more than one-tenth overcast, when the visibility is less than five miles, or at any time on request.

Z-Type Marker Beacon. Because the cone of silence does not always provide a positive and reliable means of determining the exact position of a radio range station, Z-type markers are installed at most radio range stations for this purpose. A special receiver must be installed in the airplane to receive the signals which are transmitted on a high frequency—75 megacycles. The Z-marker antenna localizes the signal zone within a teardrop-shaped space immediately above the station. The signal may be received visually or aurally, depending on the receiver; but visual reception only is provided by USAF receivers. The marker beacon light, on the pilot's instrument panel, flashes on as the airplane enters the cone of silence and remains on until the airplane emerges from the cone. The duration of the Z-marker signal increases with increasing flight altitude.

Fan-type Marker Beacon. Fan markers are high frequency (75 megacycles) radio transmitters usually installed twenty to thirty miles from the radio range across one or more of its on-course signals. They are not equipped for voice transmission. The antenna of the beacon produces a high intensity signal in a space shaped like a thick fan, immediately above the transmitter. This signal may be received either visually or aurally, depending on the receiver; in USAF aircraft, it is received visually by the equipment used to receive the Z-type marker signal. The markers around a range station may be identified by a succession of single dashes, or by groups of two, three or four dashes. The single-dash identification is always assigned to the on-course leg directly true north from the station or to the first on-course in a clockwise direction from true north. The groups of two, three or four dashes are assigned respectively to the second, third and fourth courses clockwise from the single-dash beacon.

Weather Information

The federal airways get weather information from the U. S. Weather Bureau and the Civil Aeronautics Board. This information is sent in hourly teletype sequence reports to weather-reporting stations along the airways. Such stations include most radio range stations, USAF Airways Communications Stations, airport traffic control towers and CAB radio communications stations. Besides giving weather information on request for any vicinity, the stations transmit regular local weather broadcasts on the twenty-ninth minute of every hour.

Radio Facility Chart

The **Air Force Radio Facility Chart,** T.O. No. 08-15-1, is a manual of important data on airports, radio range stations, marker beacons, and airways in the United States and southern Canada. In the main section are thirty-five charts, each covering one section of the United States. The code symbols, definitions and rules used on these charts are explained on Pages 2 and 3 of the manual. An index map on the back cover shows which chart to use for a given area.

Each chart shows:

(1) Airways—color, minimum safe altitude to fly in each direction, the control area they lie within.

(2) Radio range stations—call letters, frequency, beam direction, A and N quadrants.

(3) Airports—tower frequencies.

(4) Marker beacons—name, code, signal, distance from radio range.

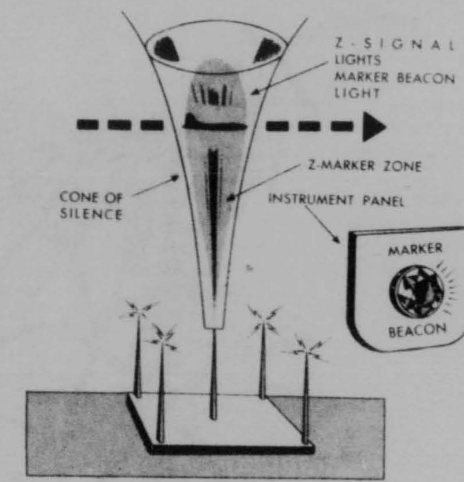
(5) Nondirectional homing beacons transmitting continuously.

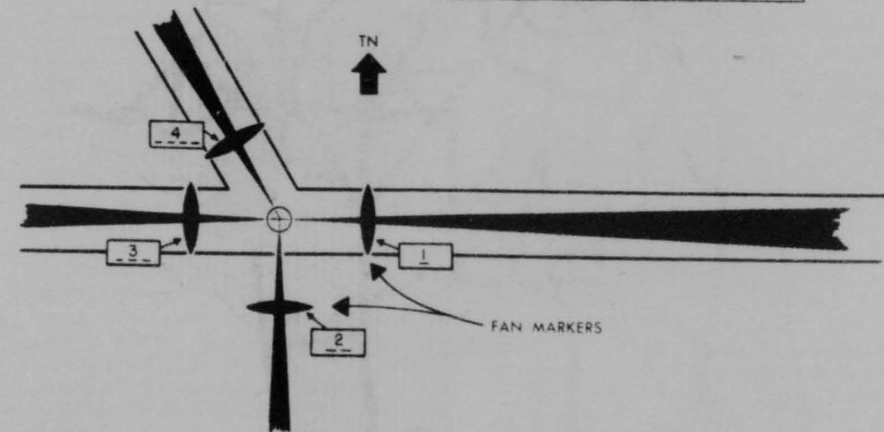
Facing each chart is a table which lists:

(1) Airports—name, frequency guarded, frequency broadcast and elevation.

(2) Radio ranges—name, call letters, code, class of station, distance, and direction from range to airport (if any).

These additional charts are in the back of the manual: (1) Geographical coordinates of all radio navigational aids in the United





States.

(2) List of radio aids to navigation—call letters and frequency.

(3) Charts showing danger areas, training areas and obstructions.

In the center of the volume is the planning chart which shows the entire United States, all radio range stations, and their distances apart along the airways.

Airways Traffic Control

Every military pilot is required to obtain approval of his flight plan before he departs on any flight other than a local flight. In good weather, when the airplane is on **Visual Flight Rules (VFR),** notification of the ETA is wired from the point of departure to destination.

Airway Traffic Control (ATC) is the agency in charge of every flight in bad weather. When aircraft are on **Instrument Flight Rules (IFR),** ATC approves their flight plan in respect to known air traffic conditions. After such approval, pilots must comply strictly with the approved flight plan, except in emer-

AIRWAYS MAP OF UNITED STATES SHOWING AIRWAY TRAFFIC CONTROL CENTERS

RESTRICTED

gency. Before any change is made en route, the change must be approved by ATC.

All calls to ATC from the air are relayed through range stations, operated by USAF Airways Communications stations or control towers. ATC cannot be contacted from the air. While en route, the pilot must report the progress of his flight to ATC. At ATC centers, this information is recorded on plotting boards which show the altitude and time separation of various instrument flights along the airways.

Airway Traffic Control centers, located at junction points along the airways, are shown on the radio facility charts. Airplanes on instruments must contact the ATC center before crossing or entering an airway.

Each of the four airways listed on the facility charts has a designated color. Green and red airways run east and west; amber and blue airways run north and south. Airplanes flying north or east must fly at an odd altitude (that is, 1,000 ft., 3,000 ft., 5,000 ft., etc.); those flying south or west must fly at an even altitude (that is, 2,000 ft., 4,000 ft., 6,000 ft., etc.). While on airways, airplanes always must be flown to the right of the beam. The altitude shown on each airway in the radio facility chart is the minimum safe altitude for that section of the airway.

Each airway has a priority rating. Green has priority over amber, amber over red and red over blue. The name G-A-R-B-O will help in remembering this order of priorities. At airways intersections, the airplane which is flying on the right-of-way airway will maintain its altitude; the airplane on the other airway must climb 500 ft. The "O" in Garbo means off the airways—no priority.

Airport traffic control towers are maintained at most airports. During VFR conditions, the tower operators have control over air traffic in the vicinity of the airport, directing take-offs, landings, taxiing, and related maneuvers.

Other Radio Aids

Marine Marker Beacons. These beacons are small radio transmitting stations, usually arranged in groups of three along a sea coast. Transmitting on the same frequency, they make it possible for the navigator to take three bearings with a minimum of tuning. One station sends its identification signal (a letter in International Morse code) for one minute; then the other two stations follow in turn. This procedure is repeated three times during a schedule and in clear weather two schedules per hour are usually transmitted; in bad weather they are repeated continuously. The reliable range of these stations, which were designed primarily for marine navigation, is from 10 to 200 miles, depending on the power of the transmitters. On aeronautical charts, the symbol for the marine marker beacon is a dot within a circle, or a solid circle with the letters RBn beside it. In a box adjoining the symbol are the call letters, frequency, and schedule of transmission.

Radio Direction Finder Stations. Radio direction finder stations, which are located along the coast and used mainly by naval forces, take bearings on the transmitters of ships and airplanes. As a rule, RDF stations are arranged in groups of three, with one of the three designated as the master and plotting station.

To request that a group of RDF stations fix the airplane's position, the radio operator sends the master station the appropriate **"Q" signal (QTF).** (Q signals covering many types of request are listed in AACS Manuals.) The radio operator then awaits instructions.

The master station, after notifying the other stations of the RDF group, directs the airplane to send its identification signal followed by a 20-second dash, repeated as many times as requested by the station. Then the other stations take bearings on the airplane and telephone them to the plotting station. Here the bearings are plotted, the fix evaluated, and the results transmitted to the airplane. If the RDF stations cannot obtain good bearings, the word "doubtful" will accompany the results. The entire procedure takes only a few minutes.

On aeronautical charts, each RDF station is indicated by a dot within a circle, with the letters "RC" near the circle. In a box beside the symbol are the station's call letters and frequency. The normal RDF frequency is 375 kcs. All coastal RDF stations use this frequency; in case of emergency they will take bearings on a 500 kc. transmitter.

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Part 3 - APPLIED AIR POWER

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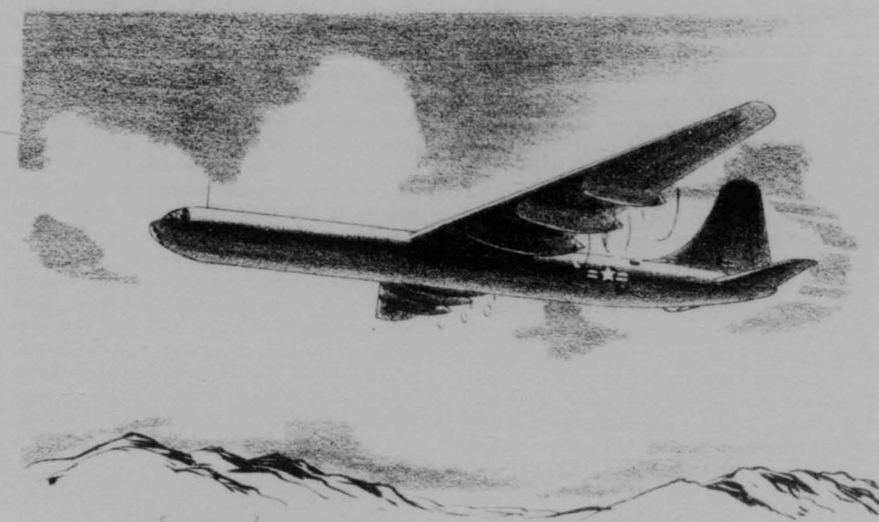
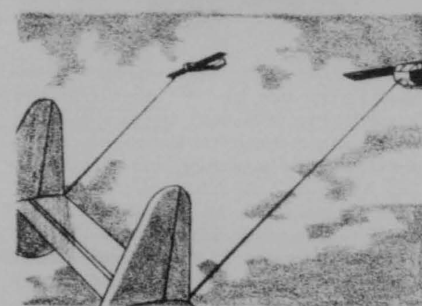
CHAPTER I - TYPES OF MILITARY AIRCRAFT



SECTION I - GENERAL

Military aviation as we know it today stems from the flight of the Wright Brothers, since almost all present-day military aircraft are of the heavier-than-air variety. However, mankind has thought about flying and experimented with flying throughout recorded history. Ancient peoples endowed their deities with the power to fly. The idea that man could fly has been one of the most persistent ideas down through the ages. "Our modern progress in aviation," writes Professor Berthold Lanfer of the Field Museum of Natural History, "is not solely due to efforts of the present generation, stupendous and admirable as they may be, but presents the process of a gradual evolution of ideas which have grown out of the imagination, endeavors, experiments, triumphs, and failures of many past ages."



When the Wright Brothers did finally free man from the earth by building their flying machine, considerable attention had already been paid to the idea of aerial warfare. The fact that so much of the development of aviation has been predicated upon its potential use in warfare is unfortunate: but today, we are in a position that enables us to look forward

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to the time when a strong air force will make costly surface warfare unnecessary.

With the advent of the heavier-than-air craft, the way was open to really develop the air weapon. The airplane was used to considerable extent in World War I and, by 1920, had really begun to prove itself. It was no longer merely the eyes of the Army. British fighters had fought off Zeppelins on their way to London. The German fighter had, for a time, been predominant in aerial combat because it mounted machine guns which fired through the propeller. Aerial bombardment had raised the prestige of the air weapon. Planes had flown several hundred miles into enemy territory to bomb selected targets and other missions had been assigned to aid the armies in the field.

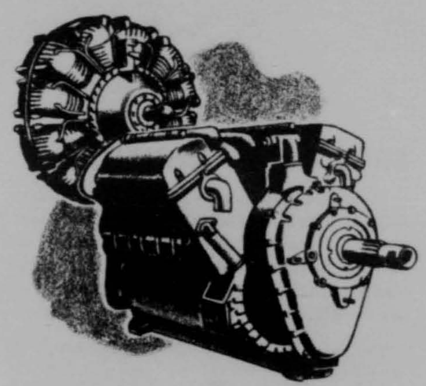
The best heavier-than-air bombardment aircraft of World War I were able to drop but a half a ton of explosives on a target and most bombers were capable of carrying only a few hundred pounds for short distances. The numerous bombing raids which were flown during the conflict had little effect upon the outcome.

The United States had been caught almost totally unprepared for air action in World War I. American-built aircraft did not start to reach the combat zone in any large numbers until the end of the war, and then they were an adaptation of a European design. The greatest achievement in aviation production attributed to this country was the Liberty engine. This engine, created jointly by several designers, turned out to be a lifesaver for the fledgling aircraft industry. By the end of the war, the Liberty engine was being produced at the rate of 46,000 per year.

When the first World War ended, we had some British-designed De Havilands and the old Curtis Jenny, neither of which had much range or speed. During the succeeding years, the design and capabilities of the airplane showed decided progress. In 1923, a coast-to-coast, nonstop flight was made. A group of Army officers had flown around the world. Jimmy Doolittle and others were pushing the speed mark up to 250 miles per hour and new endurance records were set.

In these post-war years airmen also were becoming aware of the fact that the development of the airframe was exceeding that of the power plant. When the B-15 and the B-19 were built, they were the largest land planes ever constructed. Yet neither ever became more than an experimental plane, principally because no engine had been developed with the power required to give the airplane its best performance. This was true of many of the aircraft of this period.

A constant argument had been going on for many years concerning the relative merits of the in-line, liquid-cooled, reciprocating engine and the radial, air-cooled, reciprocating engine. The in-line engine was trimmer and lent itself to a more streamlined configuration as in the F-51. The radial engine was lighter per horsepower and more powerful, but had a greater frontal area as in the F-47. The in-line engine required a liquid coolant which added weight and made it much more vulnerable to enemy fire. Although this controversy was still being waged at the beginning of World War II, most American fighters and all bombers and transport planes were designed for the radial engine.



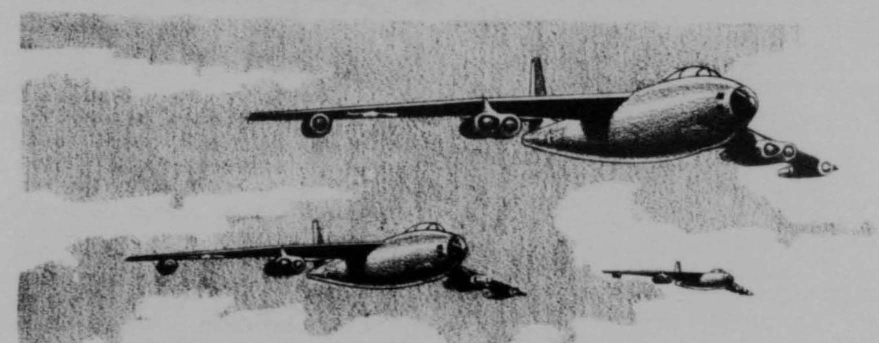
Meanwhile, a new engine was being developed. On January 16, 1930, Air Commodore Frank Whittle of the RAF filed an application for his first jet-propelled engine patent. The principle of jet propulsion was not new; in fact it is over 2,000 years old. But even by 1941 the gas-turbine jet engine was as novel as the reciprocating engine had been in 1910. The gas turbine finally had provided a power plant which the air weapon had always needed.

During the late 1930's and early 1940's, various authorities were quoted as saying that the limit of aircraft speeds had been reached. Many stated that 600 miles per hour would never be exceeded and most of them "proved" that no aircraft or human being could ever exceed the speed of sound. Today, no real authority would attempt to set even theoretical limits on the speed of aircraft. This is an amazing commentary upon the potential of the jet power plant. The X-1, a rocket-propelled aircraft carrying a pilot, has already exceeded the speed of sound.

In light of these developments, it is safe to say that the air weapon has come of age. The attainment of any desired speed is no longer an unpredictable problem. The attainment of a desired maximum range is still not entirely solved; however, piston-driven aircraft in current use are capable of ranges up to 10,000 miles. Jet aircraft have remained aloft for over nine hours and more efficient engines and new fuels will increase their range. Meanwhile, progress is being made in the field of nuclear energy for aircraft propulsion.

The situation is now reversed. The power plant has outdistanced the airframe. Aircraft manufacturers are doing their utmost to stay abreast of engine developments. Never were so many designs being tested. Today, aircraft size is no deterrent to speed. Already planes the size of the B-29 have flown as fast as all but a few of the more radical fighters. Bombers with speeds of 700 miles per hour are no longer limited to the drafting board and such aircraft are being flight tested daily.

SECTION II - TYPES OF MILITARY AIRCRAFT



1. BOMBERS

The bomber is the principal weapon of air power. It packs the punch. Until the advent of the jet engine, the bomber was looked upon as a relatively slow craft which needed to carry a considerable amount of firepower to defend itself. It also depended on strong fighter support, and in some cases, had to operate at night for protection.

Today, jet bombers are sleek, highspeed planes, in some instances as fast as the fighters which might accompany them. The great power of the jet engine has moved the bomber into the high speed class.

During the war several types of aircraft were modified for uses other than that for which they were designed. For example, the P-51 fighter was equipped to carry bombs in external wing racks and used as a dive bomber. It was then called the A-36. Today, there are three basic types of bombers: light, medium, and heavy.

Light Bombers

The light bomber has taken the place of the old attack plane. It is light, has a relatively high speed, and is powered with two engines. It operates tactically with about a 400 to 500 mile radius of action. In addition to a bomb load carried in the bomb bay, these planes may carry rockets and are equipped with machine guns for their own protection. Some models can be fitted with a nose section in which are installed eight 50 caliber guns, or possibly cannon, and are used for strafing.

Medium Bombers

Medium bombers are planes in the B-50 class with an effective radius up to 1,500 miles. This may be extended somewhat. In general, the medium bomber is not a long range type. Most tactical missions and a great proportion of strategic missions fall within its radius of action. Some of the newer types, the B-45, B-46, B-47, (all jets), will have very high speeds but rather short ranges. However, the range of jet bombers can be expected to increase with the development of new engines and fuels. Although the medium bomber carries heavy fire power for its own protection, it is, nevertheless, dependent upon fighter protection for deep, daylight penetration of enemy territory. The top bomb load in this class is about ten tons, although it varies considerably with the aircraft as well as the mission to be flown. The medium bomber is perhaps the most versatile of the bombers. It is the general purpose weapon of an air force. It is equipped for all-weather operations, radar bombing, and in some cases, may extend its range by mid-air refueling.

Heavy Bombers

The heavy bomber is the backbone of the Air Force, the weapon with which the strategic concept of air power is implemented. It is designed with the greatest possible range and bomb-carrying capacity. It contains extremely heavy fire power for its own protection, and in some cases, may even carry its own parasite fighters.

Incorporating all of the latest all-weather flying and bombing equipment, the heavy bomber is a veritable flying electronics laboratory. At the present time, the heavy bomber in operational use in the Air Force is the B-36. Powered by six reciprocating engines, with 4-auxiliary jet engines, the B-36 has proven its ability to carry a large load a great distance. Just recently a B-36 flew 9,600 miles with 10,000 lbs. of bombs.

During the early days of World War II, there was controversy over the type of heavy bombardment aircraft the Air Force should employ. One school of thought, backed largely by the example of the RAF, called for a medium range, large-capacity aircraft. Since it was planned that the bomber would be protected by a large fighter escort, defensive armament was kept to a minimum. This school of thought, considering the bomber as mainly a cargo carrier, had some validity, particularly for the RAF since their prospective targets would be within fighter range. Also, it was planned to attack at night for further protection.

The other school of thought considered the heavy bomber to be something of an aerial battleship. It was to be able to fly long missions without fighter cover, and capable of defending itself with its own armament. This was the American view. It proved successful because early in the war, bases in France were lost, leaving England as the only base of operation. This put most of the targets in Germany beyond the range of protecting fighters. The RAF, with its heavy bombers lacking protective fire power, operated under cover of darkness while the USAAF, with its B-17's and B-24's heavily armed, was able to reach into industrial Germany in daylight.

In the Pacific, this choice of a heavily-defended, long-range bomber was particularly advantageous because the great distances and the small supply of escort fighters left the protection of the bomber formation up to itself. When the B-29 became operational, it became at once the best self-defended aircraft in the world. It carried tremendous fire power; furthermore, groups of guns could be operated remotely by one gunner.

Looking into the future, one finds that the general characteristics desired of our heavy

Figure 1-1 U. S. Air Force Bomber Aircraft

bombers may be set down with little trouble.

In regard to range, the radius needed to hit the majority of the targets offered by our potential enemies is about 4,000 nautical miles, if operations are to be conducted from our present outlying bases in Alaska, Newfoundland, and Greenland. If operations are to originate from the United States, the minimum radius needed is about 5,000 nautical miles. Even then, it may be necessary to resort to range extension by refueling on vital targets.

The speed obviously should be as high as possible since speed in itself is some protection against all forms of opposition. The degree of protection is, of course, proportionate to the speed which can be attained.

The bomb load should be as high as possible because conventional bombs undoubtedly will be used on certain targets to avoid the tactical as well as the economic and political complications that might result from the use of the atomic bomb. The minimum satisfactory bomb load should be one atomic bomb.

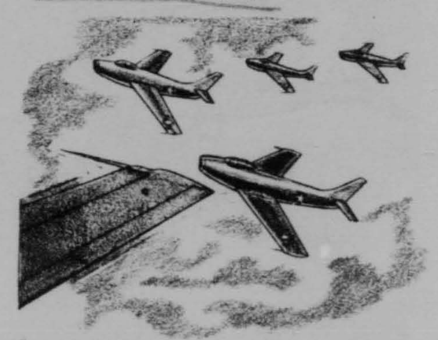
Ability to hit the target under any conditions of visibility must equal that of visual bombing. This is as important with the atomic bomb as with any other, even considering the relatively high destructive capacity of this bomb. The fact still remains that strategic bombers must be capable of hitting specific targets, as well as general areas.

Effective means are needed to counteract radar-controlled night fighters and antiaircraft guns. There is every reason to believe that the night fighter of the future will be a highly potent weapon, even though it probably will not approach the effectiveness of the day fighter for some time to come. The threat of the night fighter must, therefore, be recognized and the bomber must be equipped with an adequate defense against this type of attack. Failure to do so might well mean excessive losses. It will be necessary to minimize the effectiveness of radar-controlled flak by jamming or some other yet to be developed method.

Precision, all-weather navigation will be a necessity. Long range operations will present some very difficult problems in navigation because of weather, long overwater flights, unfamiliar terrain, flights over polar areas, and other factors. Our bombers, therefore, should be equipped with all the feasible devices available for quick and accurate position plotting. These devices should include radar, radio, automatic position plotting, rapid celestial observation equipment, and any other helpful device that may be developed. This is important in assuring that the aircraft reaches the target and returns.

The requirement for all-weather aircraft is obvious and necessary. Bomber development virtually has reached that point now.

Whatever the details may be, it is certain that the bomber of the future will have a very high speed; it will be well armed; it will be capable of carrying the atom bomb; and it will probably be able to reach any target of importance in the Northern Hemisphere from home bases.



2. FIGHTERS

The fighter is a highly specialized aircraft. As its name indicates, it is designed for one mission—to engage the enemy in the air. This does not mean that the acrobatics of World War I, or the sweeps of World War II, will be the methods employed. The high speed of the modern fighter will dictate that it hit hard, accurately, and once.

Interceptor

The interceptor is a more specialized type of fighter. It must be capable of getting into the air and up to operational altitude in a very short time. It will not be required to fly long or far, so it will not need a large fuel capacity. It will be home-based, and will be

GCA - Ground Control Approach

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used predominantly against enemy bombers. Its armament is undergoing revision from the standard 50 caliber machine guns of World War II. Because of the high rate of closure between the modern interceptor and its target, the time of effective fire is extremely brief. Therefore, the rate of fire of the machine gun must be increased. Attempts are being made to arm the interceptor with rockets to increase its fire power and effectiveness. These rockets would presumably contain proximity fuses and it is hoped that they will incorporate some homing device which will guide them to the target. While the armament designers are working on these problems, the aircraft engineers are faced with the problem of removing every unnecessary bump, corner, or other protuberance which produces drag on the aircraft. Guns and rockets necessarily do this, so attempts are being made to shield or streamline them as much as possible.

All-weather Fighter. The all-weather fighter is a fighter equipped with electronic apparatus which will enable it to detect and destroy the enemy at night and under adverse weather conditions. At present, the F-82 is the standard all-weather fighter.

Escort Fighter. The primary difference between the escort fighter and the interceptor is the long range of the escort fighter which enables it to accompany bombers on long range missions. Not long ago, an F-82 flew nonstop from Hawaii to New York, a distance of close to 5,000 miles. With the jet fighters currently available, this distance could not be equaled. However, one jet fighter, the F-85, has been designed to fit into the bomb bay of a large bomber. It could be carried by the mother ship into the combat zone and there released for operational use. The parasite fighter can be recovered in flight and returned to the bomb bay of the carrier plane. Some such system may well be the answer to the problem of fighter range extension. Towing and mid-air refueling also are being tested.

During the later stages of World War II, the escort fighters actually covered the entire route of the bombers and are credited with a good share of the success of the long range, daylight missions of the Air Force. Their psychological effect was another factor. It was said that when Goering saw American fighters over Berlin he admitted that the war was all but over. Likewise, fighters over Japan had a demoralizing effect on that country.

There is a good possibility that fighters will continue to be of several specialized types, but they will all have certain requirements which must be met.

Speed is the fighters greatest asset. The newest fighters are now pushing at the sonic barrier. The X-1 has already exceeded the speed of sound in test flights. The F-86, F-88, and F-89 also can be expected to exceed the speed of sound and present indications are that the quest for more speed in fighters will continue.

The range of which the fighter must be capable will depend upon the primary use for which it is intended. Whenever any airplane has its load increased, the speed and the rate of climb suffer; therefore, any increase in the range capabilities of a fighter are made at the expense of its speed. However, the fighter must, in general, have enough fuel to get it to the target and return and to fight at the target a sufficient time to be effective. It now appears that any strategic escort fighter should have a radius of action of at least 2,000 miles or be capable of being towed or carried with the bomber force.

Firepower on a fighter must be heavy enough to bring the enemy bomber or fighter down or to damage it severely in the shortest possible time. The use of armor makes it necessary that the weapons used be capable of penetrating and damaging the unarmored part of the enemy plane to such an extent it will be destroyed or at least rendered ineffective.

Ability or means to hit the target is a must for the fighter. There should be an automatic range and deflection calculator which will work with minimum help from the pilot. In the high speed fighter, little time will be available for sighting and firing. It must be used to good advantage.

That the fighter must be maneuverable needs little elaboration. Pilot blackout must be postponed as long as possible. Maneuver-

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Figure 1-2 U. S. Air Force Fighter Aircraft

ability must be as good or better than that of the defending interceptors.

3. TRANSPORTS AND GLIDERS

Another type of military aircraft is the transport plane. This type is usually designed for a specific purpose. The very large transports of the C-99 class will be used for long hauls with vital loads. They will be indispensable in areas where water transport is too slow or impossible. Much of the equipment of the Army today is being designed with a view toward air-transportability. For troop movements, transports need not be very large. Because it is to be expected that many troop transports will be required to land in forward areas upon small and undeveloped bases, several medium transports have been designed specifically for that type of operation. The C-119 "Packet" is a fine example of a troop and cargo carrier. Recently, this plane was equipped with track-type landing gear to enable it to operate from undeveloped fields. Another version of the C-119 is being constructed with a detachable "pod" for a fuselage. A fully-loaded "pod" could be attached to the air frame and flown to a given area. There it could be detached quickly and another fully loaded "pod" could be flown back.

Transport aircraft, generally, are sturdy, reliable types, built for their carrying capacity. They are not as fast as other types and are generally not armed. Many cargo plane manufacturers are looking to the jet propulsion field for greater speed and power.

To augment the transports, gliders were used extensively during World War II. They usually are built along strictly utilitarian lines. These may in the future be supplanted by small transports which may be used over and over again. Gliders in actual operations usually make a one way trip.

4. TRAINERS

Training planes are those developed specifically for flight school purposes. All types of aircraft are used extensively for training of one kind or another, but the trainer is used mainly in the flying schools.

The modern primary trainer is the first aircraft the fledgling pilot flies. It is a very airworthy, nearly fool-proof type, but built with many of the controls, instruments and equipment which are found in the combat planes. When the student becomes proficient in the primary trainer he is ready to fly the advanced trainer.

The advanced trainer may or may not be a special training type. Ordinarily, the student progresses from the primary trainer to the advanced trainer and is classified either as a bomber pilot or as a fighter pilot. The advanced single engine trainer is designed to prepare the student for such planes as F-51, F-47, and jet fighters. As a matter of fact, the F-51, F-47, and TF-80 are themselves used as advanced trainers in the last stages of training. The advanced twin engine trainer is designed to prepare the student for any multiengine aircraft.

5. MISCELLANEOUS AIRCRAFT

In addition to the major types of planes described above, there are many more types available for Air Force use. Some of these are planes used for purposes other than that for which they were designed. Others are engineered for specific missions.

The aircraft used for air-rescue work for example, are, with two exceptions, conventional bombing planes so modified as to enable them to drop lifeboats to personnel in the water. The amphibian is a specially developed aircraft particularly helpful in air-rescue work since it can operate from either land or water. The helicopter is becoming increasingly important in both air-rescue and liaison operations. It is able to land and take off in very small areas, and it can pick up personnel from otherwise inaccessible places.

Reconnaissance and photographic aircraft played an important part in the past war. When the first airplanes were delivered to the Army they were considered to be the eyes of the ground troops. Today, they are still the eyes of the armed forces, but the reconnaissance mission has broadened considerably. Tactical reconnaissance takes place in the combat zone, while strategic reconnaissance is carried deep into enemy territory. Much of the reconnaissance of today is photographic and aerial mapping.

Probably every combat aircraft of the Air Force has at one time or another served as a

Figure 1-3 U. S. Air Force Cargo Aircraft

Figure 1-4 New and Experimental USAF Aircraft

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reconnaissance or photographic plane. With one exception, no airplane has been developed by the Air Force for the specific purpose of reconnaissance. The planes have been basic types, stripped of all armor and armament, with cameras installed. They are dependent upon superior speed for protection. The one exception is the "Rainbow", a four-engine aircraft designed for high-speed, high-altitude, photographic reconnaissance. Just recently, this plane flew from California to New York making a strip map as it flew. It took a continuous picture of its flight path all the way across the United States from an altitude of about 40,000 feet.

Ordinarily special aircraft are not built solely for experimental and service test functions. However, at times it becomes necessary to test some new design or power plant with an experimental model. Today, the Air Force classifies these planes with the designation "X", signifying those purely for experimental purposes. The X-1 is the best known of this type. It was designed to explore the speed range around the speed of sound. From lessons learned with this plane, future aircraft can be constructed directly as operational types. Some new models are not experimental. They have been tested but not yet accepted for operational use. These are classified as service test aircraft. The classification does not cover any particular type as all new aircraft designs go through the service test stage before being accepted.

A drone is any conventional aircraft modified to be flown by remote control without a crew aboard. During the Bikini atom bomb tests, drone aircraft flew through the radioactive cloud taking pictures and samples of the air above the blast. Later three of these drone B-17's flew, in formation, from Hawaii to Muroc, California, to demonstrate the capabilities of radio controlled aircraft. Drone fighters, F-80's, have been tested with the object in mind of using a similar system of remote control in fighter action.

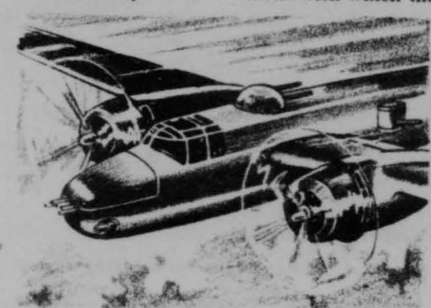
SECTION III - DESIGNATION OF USAF AIRCRAFT

The particular tactical and operational employment of an airplane determines its USAF classification. By "tactical and operational employment" is meant its use for bombardment, training, etc. When an airplane performs more than one function, the secondary function is designated by the first letter and the primary function by the second letter, e.g., an F-80 fighter used as a trainer would be designated TF-80. If the same fighter were used as a reconnaissance plane it would be designated a RF-80. The model of a particular classification is designated by a number, e.g., B-29. Furthermore, there may be a series of a particular model on which minor modifications have been made. Such a series is designated by a letter following the model number, e.g., B-29B.

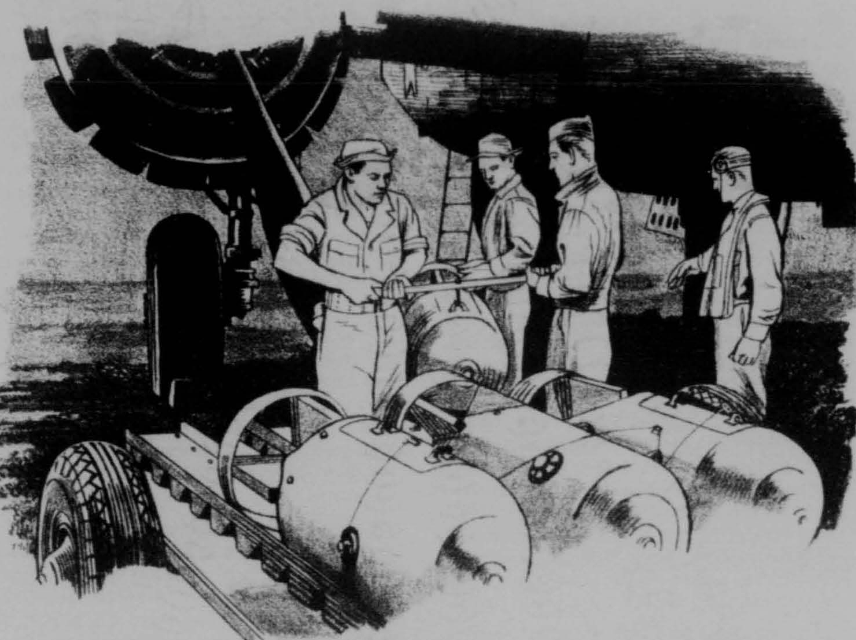
A few USAF aircraft designations are set forth in the following list:

Bombardment	B	(B-36)
Cargo	C	(C-54)
Fighter	F	(F-86)
Rotary Wing	R	(R-5)
Trainer	T	(T-6)

So much for the airplanes themselves. The next chapter will deal with some of the equipment with which these aircraft fight.



CHAPTER 2 - AIRCRAFT FIGHTING EQUIPMENT



SECTION I - RADAR

1. RADAR PRINCIPLES

Radar—Radio Detection and Ranging—is one of the great scientific developments of World War II. Its development, like the development of many other great inventions, was mothered by necessity—namely, the necessity for offsetting the offensive power of the airplane. It was in the detection of ships and aircraft that radar found its first usefulness.

Radar is, by definition, an application of radio principles by means of which it is possible to detect the presence of objects in space. The principle upon which radar operates is very similar to the principle of sound wave reflection. If a person shouts toward a cliff, or some other sound-reflecting surface, he hears his shout return from the direction of the cliff. In other words, he receives an echo. What actually takes place is that the sound waves generated by the shout travel through the air until they strike the cliff. Some of the reflected waves return to the original spot, where the person hears the echo. Some time elapses between the instant when he shouts and when he hears the echo, since sound waves travel through the air at approximately 1,100 feet per second. With suitable devices, it is possible to measure the distance and di-

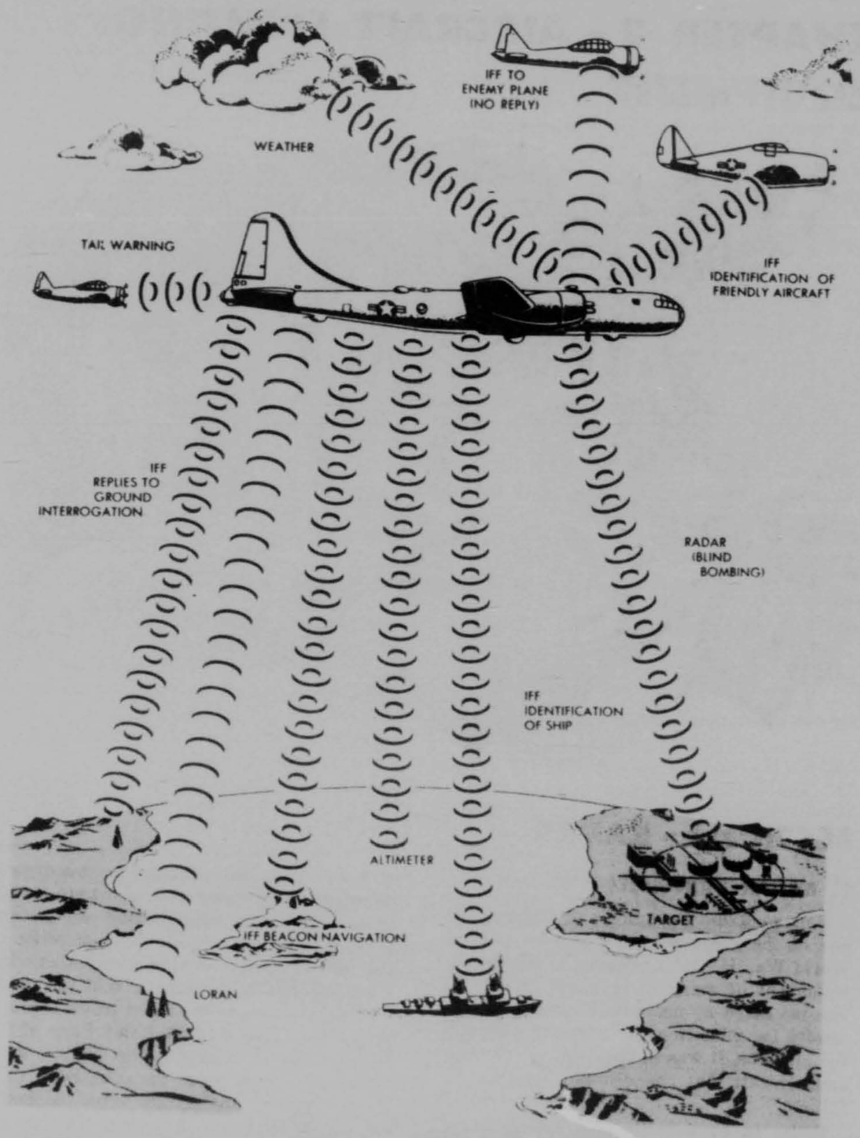


Figure 2-1 Aircraft Radar Aids

rection of the cliff from the person as well as the height of the cliff.

All radar sets work on a principle very much like that described for sound waves. In radar sets, however, a radio wave of extremely high frequency is used instead of a sound wave. The energy sent out by a radar set is similar to that sent out by an ordinary radio transmitter. The radar set, however, has one outstanding difference in that it picks up its own signals. It transmits a short pulse and receives its echoes, then transmits another pulse and receives its echoes. This out and back cycle is repeated from 60 to 4,000 times per second depending upon the design of the set. If the outgoing wave hits no object in space it simply travels on out into space and is not reflected.

If, however, the wave strikes an object such as an airplane, a ship, a building, a hill, or a cloud some of the energy is returned as a reflected wave. If the object is a good conductor of electricity or is large, a strong echo will result. If the object is a poor conductor or is small, the reflected energy is small and the echo is weak.

Radio waves of extremely high frequency travel in straight lines at a speed of approximately 186,000 miles per second. Thus, there will be an extremely short time between the sending of the pulse and the reception of its echo. It is possible to measure the interval of elapsed time between the transmitted and received pulse with great accuracy — even to one ten-millionth of a second.

The directional antennas employed by radar equipment transmit and receive the energy in a more or less sharply defined beam. Therefore, when a signal is picked up, the antenna can be rotated until the received signal is of maximum intensity. The direction of the object or target is then determined by means of the position of the antenna. The echoes received by the radar receiver appear as marks of light on a specially-constructed instrument called an oscilloscope, or scope for short. This device measures the time required for the radio energy to travel out to the target and return. It usually is calibrated in miles so that the range to the target may be read directly off the scope.

2. RADAR TYPES

The discussion of the types of radar sets that have been developed for specific uses will be in general terms.

If the Air Force is to accomplish its mission on an around-the-clock and all-weather basis, equipment is needed to make such operations effective. There must be navigation devices which make possible precision navigation during instrument flight conditions when neither ground observations nor celestial observations can be obtained. There must be a device to permit accurate bombing of targets when smoke, haze, clouds, or dust obscures the target. There must be warning and identification devices to warn an aircraft of the approach of another aircraft and to identify it. And lastly, there must be a system to aid aircraft in landing at bases when ceiling and visibility are below safe landing conditions.

The navigational and bombing requirements were met by the use of essentially the same type of radar sets. In order that the airborne radar set could be used for navigational purposes, it was necessary to display the received signals in some way that would be useful to the operator. Basically, the chosen method for displaying the received signals was a Plan Position Indicator (PPI) scope. This scope shows the signals as spots or "pips" of light on the face of the scope. The resulting target display then shows the relationship of the targets radially for relative bearing, and by measuring their distance from the center of the scope the range to the target can be determined. (Figure 2-2) To solve the radar bombing problem, a method called "radar synchronous bombing" was developed. This method employs a computer into which necessary bomb release information is set. The computer also has a driving mechanism similar to that of the Norden bomb sight. With this computer, the radar operator synchronizes the rate of the drive mechanism with the rate of closure on the target. The bomb release time is determined by the computer and the bombs are released automatically. This bombing-device is used in conjunction with the type of navigational radar set described above.

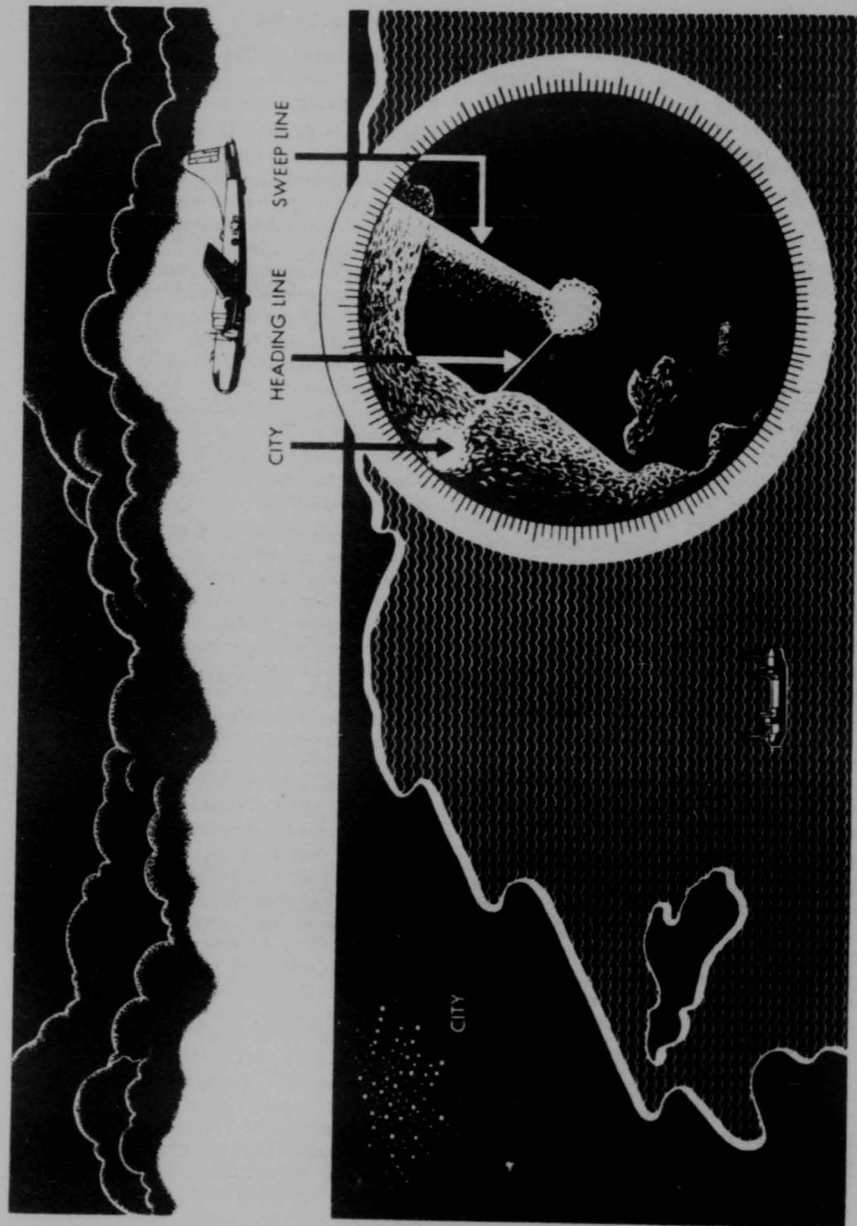


Figure 2-2 Radar Navigation

Another type of navigation and bombing radar is the Short Range Navigation (Shoran) system. It can be used for either navigation or bombing or both. The system employs the use of two ground beacons and an airborne radar set designed to trigger those beacons. It then measures the elapsed time between the transmission from the airborne set and the reception of the beacon signals. Since the exact geographical position of the two ground stations is known, the position of the aircraft can be determined with great accuracy. As the name implies, the system can be used for short range work only. A similar system, Loran, is used for long range navigation.

When using Shoran for bombing, the bombing problem is solved in terms of the distance of the bomb release point from each of the beacons. The release point is determined prior to the mission and the distance from each beacon is measured to the nearest one-hundredth of a mile. These distances are pre-set into the computer and the aircraft makes the bomb-run with one beacon being used to determine course and the other to control the bomb release.

Tail-warning radar is used to give indication of another aircraft approaching from the rear. The signal is transmitted from the first aircraft and reflected from the aircraft in the rear. Returning to the receiver, this reflected signal activates both a buzzer and a light on the instrument panel as a warning to the pilot.

The IFF (Identification-Friend or Foe) set was used extensively during the past war to identify aircraft to ground radar stations. A ground transmitter sends a signal to a receiver in the aircraft. When the signal is received it activates a transmitter in the aircraft which automatically sends a coded signal to the ground station.

The all-weather fighter depends upon radar to accomplish its mission. The many different radar sets in the aircraft enable it to search for and find its target, automatically compute the range and fire the guns without ever seeing the enemy aircraft.

All of the airborne radar equipment would be of little value to an all-weather air force if there were no provision for landing the returning plane in bad weather. A method by which this may be accomplished is the ground radar system called Ground Control Approach (GCA). The GCA system provides facilities for directing the movement of aircraft in the vicinity of an airdrome and over a predetermined glidepath for a safe approach to the proper runway under conditions of adverse visibility. Accurate and continuous information regarding the location of the incoming aircraft is presented to the ground operators in the form of range, azimuth, and elevation data by the radar portion of the system. This information is interpreted by the operators as lateral and verticle deviations from the glidepath. It is communicated to the pilot by radio in the form of instructions regarding the course he must fly in order to make a safe approach to the runway.

These are but a few of the radar systems that are used both in aircraft and in ground control of aircraft. However, they will suffice to give a general background of the types and capabilities of radar sets.

SECTION II - GUNS AND ROCKETS

1. GUNS

The primary weapon with which USAF aircraft is equipped is the 50 caliber air-cooled machine gun. It may be mounted in fixed positions and fired by the pilot as in the fighter, or it may be mounted in turrets and fired by individual gunners as in the bomber. The trend in the latter is toward central fire control, where a number of turrets may be fired by a gunner whose sighting position is remote from the turrets themselves. The rate of fire of the 50 caliber machine gun is about 1,000 rounds per minute. With the greatly increased speeds of the modern aircraft resulting in an extremely high rate of closure between fighter and bomber and an extremely short time for aiming and firing, steps are being taken to increase the rate of fire.

As to future trends in aerial gunnery, we find that while turrets, guns, and radar computer combinations are fairly accurate at ranges closer than a thousand yards, the rate of closure increases the errors of operation in direct ratio to the distance involved. Because of these errors and limitations in equipment, attention has been concentrated upon: a) heavier guns having longer ranges; b) improvements in automatic radar ranging and firing devices; c) improvements in electronic ballistic computers (for use with radar gun equipment); d) a heavier concentration of fire power for aircraft having defensive weapons, i.e., all plans for heavy bombers call for nothing less than 20 millimeter cannon; e) improvements in remote control turrets.

All these developments indicate that most major designers are working on the basic premise that as supersonic speeds are more closely approached, the human element is less capable of dealing with the increasingly complex problems of aerial gunnery.

2. AIRCRAFT ROCKETS

It is hoped that the problem of gunnery at supersonic speeds may be solved, in part, by the substitution of the aircraft rocket for the caliber 50 machine gun. The military use of present-day rockets is well known. Aircraft rockets have the same effective action as projectiles from 155 millimeter guns and are most useful against military targets such as locomotives, tanks, vehicles, buildings, boats, gun emplacements, and harbor installations as well as against enemy aircraft both in the air and on the ground.

The use of aircraft rockets has expanded at an incredible rate. In 1945, the Navy alone was spending as much as $100,000 a month for rocket ammunition. The use of rockets became axiomatic for amphibious landings after just a few trials. The reason for this sudden expansion was due to the fundamental advantages of the rocket over artillery.

In the airplane, the aircraft rocket has far greater range than the heaviest gun that aircraft could carry without major modifications. The trajectory is flatter for aircraft rockets than ground rockets because the speed of the plane is added to the initial velocity of the rocket. Consequently, the accuracy is exceptionally good. It was found that aircraft rockets fly straight to the target instead of following a curved trajectory like that of ground rockets. The principle of reaction, by which rockets are impelled forward, brings about a third definite advantage, namely lack of recoil of the mount or of the launcher. Thus, there is little of the shock of firing acting upon the airplane so that very light launching apparatus may be used. As a direct result the load and strain on the airplane is much less than if a heavy gun mount had to be carried. Although, at present, only a few sizes of rockets are in use, a wide range of rocket sizes is feasible for aircraft. The gentle take off allows high powered, but more sensitive, explosives to be used in the rockets.

The principal rocket used today by aircraft is the 5.0" high velocity aircraft rocket (HVAR) which is launched from racks under the plane's wings.

SECTION III - BOMBS

1. GENERAL

At the end of World War I, the world realized to some extent the value and importance of the airplane and the high explosive bomb as an offensive weapon. During the years following the war, there was great activity in bomb and bomb fuze development as well as in the field of bomb ballistics. When bombs were first used, they were suspended

vertically, nose down in a rack. It was soon discovered that this was not the correct position and that a bomb must be started off in a horizontal position tangent to its true trajectory. The lifting power of the aircraft increased and so did the size of bombs—from 600 lbs. to 4,000 lbs. in two years. Careful studies were made in the tactical use of bombs to determine the economical limits for the sizes of bombs. It was decided that there should be three types: fragmentation bombs, chemical bombs and demolition bombs.

2. CONVENTIONAL BOMBS

General Purpose Bombs

General purpose bombs are designed to meet the requirements of the great majority of bombing missions. The various models range from 100 to 4,000 lbs., and the percentages of explosive in this type averages 50 per cent of the loaded weight of the bomb. General purpose bombs may be used for blast, fragmentation or mining effect.

Light Case Bombs

The light-case, 4,000 lb. bomb is highly effective as a blast bomb for targets requiring no penetration. It must be fuzed to explode before the case breaks up on impact and, therefore, should be employed only on those targets against which surface blast is effective. In other respects this type of bomb resembles the general purpose bomb described above.

Armor-piercing Bombs

This bomb is designed to pierce the heavy deck armor of modern naval vessels. The case is extremely heavy and, to be effective, the bomb must score a direct hit. The effect of a near miss is comparatively minor because of the small amount of explosive in the bomb. This type should not be used against unarmored or lightly armored ships because, being fuzed with delay fuzes to permit penetration, the bomb would pass right through a light vessel.

Semiarmor-piercing Bombs

These bombs are essentially the same as the general purpose, except that the case is heavier and the explosive charge is less. This type is good for lightly-armored targets.

Depth Bombs

The depth bomb is a light case bomb containing 79 per cent of its weight in explosive. It is designed for use against submarines and is fuzed with a hydrostatic fuze which functions at a predetermined depth rather than upon impact.

Fragmentation Bombs

Fragmentation bombs are designed to produce their effect through projection of the fragments of the case, and are intended for use against personnel and light material. When employed in sufficient numbers to cover large areas, either from high altitude in clusters or from minimum altitude with parachutes, fragmentation bombs will effectively damage light material targets such as radar equipment, aircraft, vehicles, antiaircraft guns, light artillery, etc., and will produce extensive casualties among exposed personnel.

Chemical Bombs

Chemical bombs are of two types: those containing gas or smoke, and those containing inflammable material such as oil, napalm, or magnesium. They have a variety of uses, ranging from the use of smoke to conceal activity from the enemy to the use of incendiaries to burn targets.

3. ATOMIC BOMBS

The advent of the atomic bomb has put into the hands of air power the most destructive weapon man has ever known. In the explosion of an atomic bomb, matter is transformed into energy by nuclear fission. This energy, which is released, is of such magnitude and from so concentrated a source that it sets up entirely new problems in its use and in protection against it. The energy takes three forms, and all effects of the bomb can be attributed directly to the three. They are: 1) heat (similar to flash burns but greatly intensified); 2) radiation (similar to X-rays or to that from radium); 3) blast (as from a demolition bomb).

To compare the e[illegible]s of the atom bomb with those of the conventional bomb, data obtained from the atomic bombing of Nagasaki may be used. At that target, the blast effects of the bomb were on a new scale because the duration of the blast was long compared to that of a high explosive bomb. To take only one example: At Nagasaki, brick buildings suffered structural damage within a radius averaging 6,000 ft. from the impact point. Comparable damage would have been done by a 500 lb. high explosive bomb for a radius of 55 ft.; by a 1,000 lb. bomb for 80 ft.; by a 2,000 lb. bomb for 110 ft., and by a 4,000 lb. bomb for 200 ft. The area of effectiveness of the air burst of the atomic bomb against brick buildings thus was 15,000 times as great as that for a 500 lb. conventional bomb.

As for the casualties resulting from the atomic bomb, a comparison is afforded between Hiroshima and Tokyo. At Hiroshima, one B-29 carrying one atomic bomb caused 70,000 to 80,000 to be killed or missing. At Tokyo, in one raid 279 B-29's carrying 1,667 tons of bombs caused 83,000 to be killed or missing. The United States Strategic Bombing Survey pamphlet, "The Effects of Atomic Bombs on Hiroshima and Nagasaki," estimates that, based upon results obtained at those two targets, in order to equal the effectiveness of one B-29 with one atomic bomb, an attack with conventional high explosive bombs would have to be carried out by a total of from 210 to 270 B-29s each carrying ten tons of bombs.

No one is certain what the future holds in the way of the employment of the atomic bomb. General Spaatz wrote the following in Life magazine: "More than 40,000 people were killed in the British attacks upon Hamburg in July and August, 1943. In the great March, 1945, attack on Tokyo, 125,000 people perished and 75,000 more were rendered homeless in a single night by some 3,000 men in only 279 airplanes. Three attacks within fifteen hours wiped out Dresden and buried perhaps 60,000 in its ruins. These terrifying magnitudes of destruction were brought about by air power with only the conventional high explosive bomb.

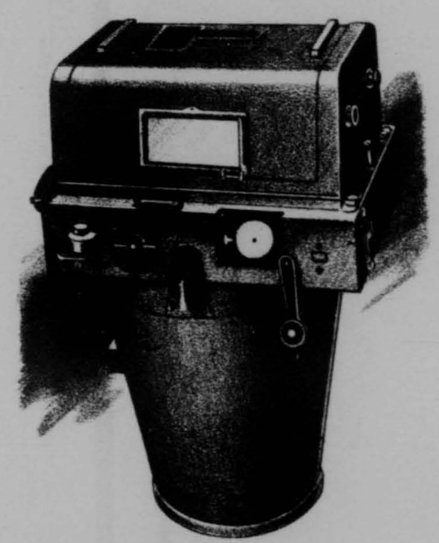
"The destructivce power of the present atomic bomb, measured by military standards, has been exaggerated by laymen. Yet the fact remains that it injects a multiplier of destruction into the effectiveness of each bomber on the order of hundreds to one. Wars that might otherwise last years may be ended in weeks, perhaps days. And campaigns that would otherwise cost the lives of hundreds of thousands of soldiers and sailors may now be the work of a few hours by a few men. Much that would have been impossible becomes possible with the atomic bomb."

SECTION IV - AERIAL CAMERAS

Knowledge of the enemy is one of the essentials of military victory. Aerial cameras and aircraft, combined with the skills of the photo interpreter, the photogrametrist, and the intelligence analysist, give the present military commander a major portion of the required knowledge. The advantages of aerial photography were recognized as far back as the Civil War. Photographers with wet plates went up in captive balloons, just behind the front lines, and took pictures of the opposing forces. Despite crude equipment and limited range the results had military value.

From these early Civil War efforts, aerial photography has evolved into an exact

science. All aerial photographs fall into two main categories: **verticals** and **obliques**. Vertical photographs are made from an aerial viewpoint with the camera axis perpendicular to the earth. Oblique photographs are made from an aerial viewpoint with the camera deflected from the perpendicular. High oblique photographs are those which show the horizon. Low oblique photographs do not show the horizon. For the many varieties of these basic types of aerial photography, specialized aerial cameras have been developed. The remaining paragraphs of this chapter are devoted to a short review of this equipment and its uses.



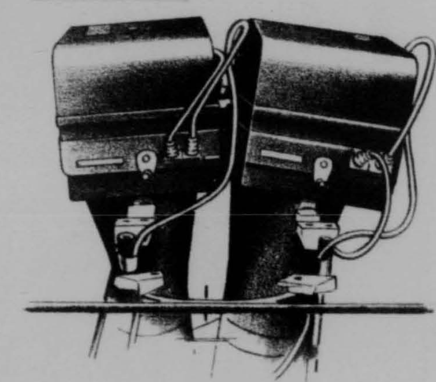
The essential parts of an aerial camera are: the lens cone, the camera body, and the film magazine. Cones vary from the 6″ with wide angle lens, to the 40″ with telephoto lens. The standard work horse in the aerial camera field is the 12″ cone. From this cone are obtained photographs whose scale is one over the altitude of the aircraft, i.e., at 10,000 feet the scale of the photograph is 1: 10,000. Controlling the entire operation of the camera is the camera body. Here are housed the winding and tripping mechanism, operated either manually or electrically; the frame, which varies from a 4″ x 5″ opening to 9″ x 18″; the film transporting assembly; and miscellaneous accessories, such as level, film counter, manual shutter release, etc. Within the magazine is housed the film. Aerial film comes in rolls whose width is either 5″, 7″, or 9″, and whose length varies from 20′ to 390′. (Figure 2-3).

Cameras shown in Figure 2-3 can be used in a variety of combinations. Some of these are:

Mapping—controlled mosaic maps, K-17 with 12″ cone, held to a maximum of 3° tip or tilt. Uncontrolled mosaics, K-3B, K-17, and K-22 with either 6″ or 12″ cone.

Tri-metrogon mapping — three K-17 cameras, with 6″ wide angle cones. One camera is vertical. The other two are the right and left obliques. Each is tilted 30° from the horizontal. Horizon to horizon photography is the result.

Pinpoints: Any vertical camera. The type depends on the military situation and the information desired.



Split-verticals: Two cameras each tilted 7° from the vertical. Normally the K-22, with 24″ cone is used for this purpose.

Hi and Lo Obliques: K-3B, K-17, and K-22 camera, with 12″ cones are tilted 15° from the horizontal for high obliques, and 30° for low obliques.

Dicing: High obliques taken from the nose of the aircraft at minimum altitude. This

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USAF AERIAL CAMERAS IN CURRENT USE

	K-3B	K-7C	K-15	K-15A	K-17	K-18	*K-19B	K-20	K-21	K-22
Oblique Camera	x	x	x	x	x	x		x		x
Vertical Camera	x	x	x	x	x	x	x		x	x
Manual	x	x	x			x		x		
Electrical	x	x		x	x	x	x		x	x
Negative	9x9	9x18	5x7	5x7	9x9	9x18	9x9	4x5	5x7	9x9
6″ Cone	x				x					x
6⅜″ Cone								x		
8¼″ Cone	x									
12″ Cone	x				x		x			x
20″ Cone			x							
24″ Cone	x	x			x	x				x
40″ Cone				x						x
Lo Altitude	x		x		x		x	x	x	x
Med Altitude	x		x		x			x	x	x
Hi Altitude		x		x		x			x	x

***Takes night photographs with photoflash bombs.**

Figure 2-3 USAF Aerial Cameras in Current Use

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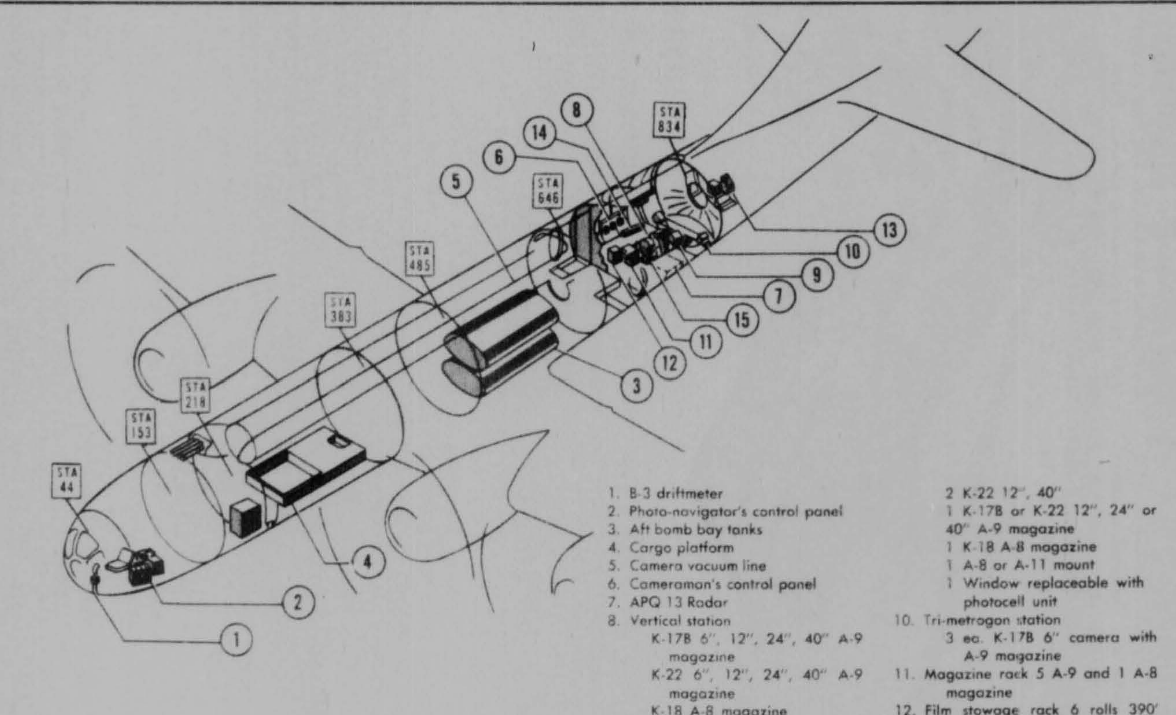
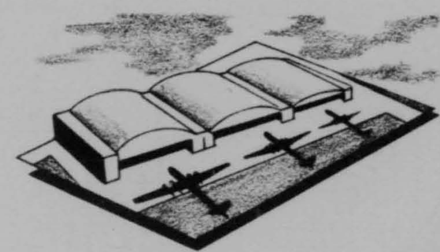


1. B-3 driftmeter
2. Photo-navigator's control panel
3. Aft bomb bay tanks
4. Cargo platform
5. Camera vacuum line
6. Cameraman's control panel
7. APQ 13 Radar
8. Vertical station
   K-17B 6″, 12″, 24″, 40″ A-9 magazine
   K-22 6″, 12″, 24″, 40″ A-9 magazine
   K-18 A-8 magazine
   K-19 (with photocell in split vertical window)
   A-8 or A-11 mount
9. Split vertical station
   2 K-17B 12″, 40″
   2 K-22 12″, 40″
   1 K-17B or K-22 12″, 24″ or 40″ A-9 magazine
   1 K-18 A-8 magazine
   1 A-8 or A-11 mount
   1 Window replaceable with photocell unit
10. Tri-metrogon station
    3 ea. K-17B 6″ camera with A-9 magazine
11. Magazine rack 5 A-9 and 1 A-8 magazine
12. Film stowage rack 6 rolls 390′ each
13. Spare window glass and K-22 spare shutters
14. H-2X automatic recording camera
15. Operator's seat

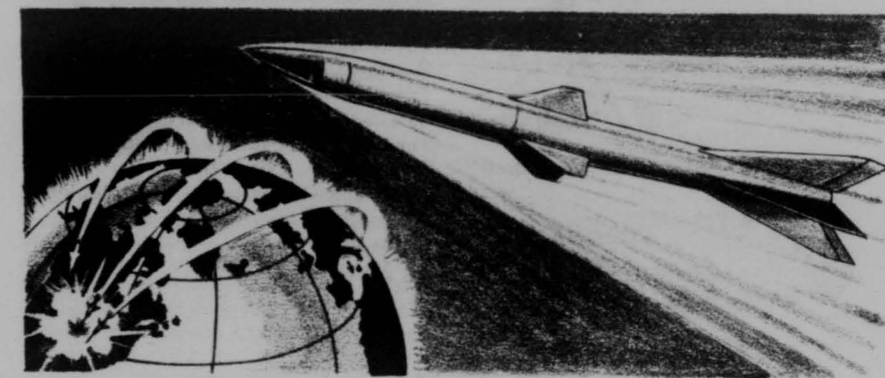
Figure 2-4 Type F-13 Photographic Reconnaissance Airplane

type of photography is also called a forward shooting oblique. (Figure 2-4.)

As mentioned in the introductory chapter, aerial cameras have been installed in almost every type of aircraft. Two types of photographic aircraft are currently in use. For short range, tactical reconnaisance the Air Force uses the RF80, which is a modified F-80. All cameras are carried in a specially-constructed nose section. For long range strategic reconnaissance, the Air Force uses a modified B-29. (See Figure 2-4.) This aircraft is known as the F-13.



CHAPTER 3 - GUIDED MISSILES



SECTION I - GENERAL

1. INTRODUCTION

Spurred on by the requirements of World War II and occupying an increasing portion of our military interest is the development of a new weapon—the guided missile. The guided missile presently is being considered as a supplement to the airplane, but may in the future supplant the airplane as the primary weapon of air warfare.

A guided missile is, simply, **any missile to which guidance control may be applied after it has been launched**. That is, it is an air vehicle which may be flown without a crew aboard. Note that it is any missile. This means that the term includes rockets, bombs, glide bombs, etc., as well as remote-controlled aircraft.

The only prewar development of a remotely-controlled missile that was actually flown in this country was a small aircraft controlled by radio from the ground or from another aircraft. These aircraft were used as targets for antiaircraft and aerial gunnery practice.

The use of guided missiles, including pilotless aircraft, as weapons was introduced effectively in World War II. The Germans used remotely-controlled bombs as well as missiles with pre-set controls for guiding them into general areas. We used bombs guided by radio and pilotless aircraft which were crashed into targets by television and radio control. These early weapons were the forerunners of others rapidly being developed into guided missiles which will travel at supersonic speeds and may be maneuvered by remote control to seek out automatically and destroy flying targets, or to bombard targets several thousand miles away.

2. DESIGNATION OF GUIDED MISSILES

Before beginning a discussion of the types of missiles, it would be best to learn the system of designating U.S. guided missiles, just as the system for designating types of USAF aircraft was learned. This system is used by the Army, Navy, and Air Force, and is applicable to all guided missiles developed by the three services.

The basic designation is a two-letter combination of the letters "A" (air), "S" (surface, or "U" (under water), in which the first letter designates the origin of the mis-

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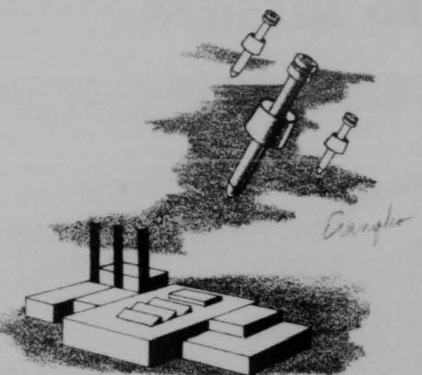
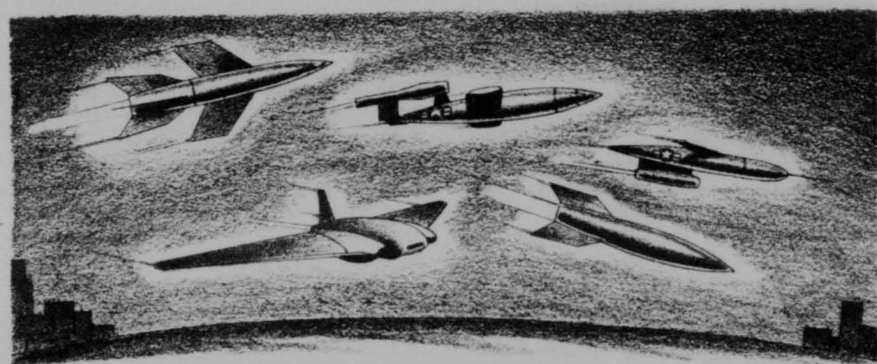


sile and the second letter designates the objective. This combination of two letters is followed by the letter "M," indicating missile. Each basic designation is followed by a service letter: A (Air Force), G (Army), N (Navy); and a model number which, in turn, is followed by a modification letter, e.g., SSM-A-3b is Surface-to-Surface Missile, Air Force, Third Model, Second Modification; AUM-N-2d is Air-to-Underwater Missile, Navy, Second Model, Fourth Modification.

With proper approval a popular name may be assigned to a missile just as types of aircraft are given popular names.

SECTION II - TYPES OF GUIDED MISSILES



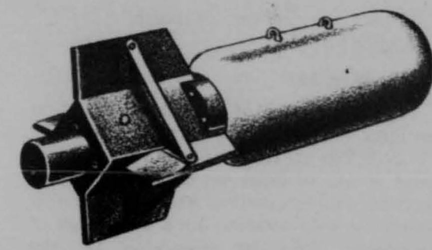
With the foregoing information as a background consideration may be given to some of the types of guided missiles developed during and subsequent to World War II. While it is neither possible nor desirable in a presentation of this nature to engage in lengthy discussion of each missile developed, it is felt that a simple description of the major types will indicate the scope of the guided missile effort.

1. UNITED STATES GUIDED MISSILES

United States missile development during the course of World War II was directed toward the successful operation of four guided missiles of the air-to-surface and surface-to-surface types. They were Azon, GB-8, Weary Willie, and Bat.

Azon

Azon is a free-falling, conventional 1,000 lb. bomb with a special tail that enables it to be steered to the left or right on receipt of radio signals from the plane dropping it. This is accomplished by a small radio receiver in the tail which activates a servo motor connected to the rudders in the bomb tail fins. Also packed in the tail are a gyro



and solenoids to change the pitch of small ailerons in the fins to prevent rolling of the bomb while in flight. The bombardier tracks the bomb by means of a flare in the tail and makes corrections in its flight by using a control box in the airplane. Azon was used quite successfully in Burma and its accuracy was estimated as being ten times greater than that of a conventional bomb against long narrow targets. It does, however, have three major drawbacks. (1) It is dependent upon clear weather because the bombardier must be able to see the bomb during its fall. (2) The altitude of release is limited to about 12,000 feet because above that altitude it becomes difficult for the bombardier to follow the bomb. (3) In order to see and control the bomb, the airplane must fly a straight and level course after release. This prevents evasive action and makes the launching plane very vulnerable.

GB-8

GB-8 is a standard 2,000 lb. bomb to which a set of twelve foot wings and control surfaces have been added, making a glide bomb.

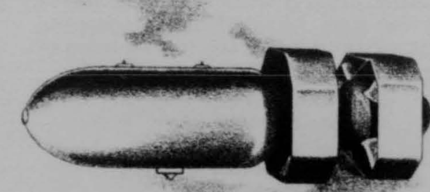
The control surfaces are actuated by radio signals transmitted by the bombardier of the launching airplane. The bombardier tracks the bomb by means of a television set in the nose of the bomb which enables him to view the area toward which the bomb is heading. The GB-8 was used to some extent against targets in Europe but the results were not sufficiently satisfactory. The bomb is too dependent upon good visibility for control; its low speed, (250 miles per hour), makes it vulnerable to antiaircraft fire, and the fact that it is carried externally slows down the launching aircraft.

Weary Willie

Weary Willies are old heavy bombers stripped down and loaded with TNT. During World War II, they were taken off by human pilots who bailed out after a mother aircraft had taken control. The Weary Willie was then flown to and crashed on the target by remote control from the mother plane. Because of intense antiaircraft fire, adverse weather, and equipment failures little success was attained. However, experimentation with remote control of aircraft is continuing.

Bat

Bat, a Navy guided missile, was an air launched, radar-homing glide bomb of 10 foot wing span and carrying a 1,000 lb. conventional bomb. Several of these missiles were used but little success was experienced.



VB-3 RAZON

Razon

Since the end of the war, the Air Force has been developing several missiles. One of these, **Razon**, is similar to Azon, the principal improvement being the added ability to control the bomb in range as well as azimuth. It is a highly accurate weapon and is believed to provide over twenty times the normal probability of hitting pin-point targets; it is thirty times as effective for maneuvering targets. Its main drawbacks are the necessity for visual control and the fact that it is possible to control only one bomb per radio channel.

Felix

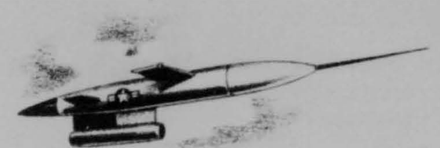
Felix is a standard 1,000 lb. bomb for attack against targets which give a differential heat radiation from the surrounding area.

VB-6
HEAT SEEKING
BOMB

Heat-homing guidance is obtained by a heat-seeker assembly in the nose which applies proper corrections in range and azimuth to a special tail assembly. The missile is accurate but limited to use in clear weather.

Navy Missiles

Brief comment should be made upon some of the Navy missiles under development. The following types are representative of the work now being done:



Two types of surface-to-surface missiles similar to the German V-1.

Two air-to-air missiles with liquid rocket propulsion.

Various glide bombs similar to the Bat, one of these having rocket propulsion to increase range.

A glider bomb towed to the launching point, with television intelligence and radio control.

A heat homing verticle bomb.

A glide torpedo.

Army Missiles

The Department of the Army has three projects now under way in the guided missile field. Two are concerned with the development of one or more types of short range, tactical, guided missiles, while the other is concerned with establishing a knowledge of supersonic flight, jet propulsion, and the makeup of the extreme upper atmosphere. It is in this latter project that the Army is firing the captured V-2s and the Army developed WAC series.

Figure 3-1 Surface to Air Guided Missiles

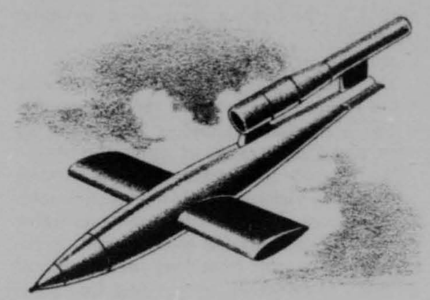
2. GERMAN GUIDED MISSILES

There is no doubt that the Germans were far ahead of the field in the development of guided missiles. They built a few air-to-air and air-to-surface missiles but their main and most successful effort was with surface-to-surface missiles, the best known being the V-1 and V-2.

V-1

The V-1 was a pilotless aircraft propelled by a pulse jet engine. It was about 25 feet

long, had a wing span of 17 feet, and weighed 5,000 lbs. Launched either from an airplane or the ground, it had a range of about 150 miles, a speed of about 400 miles per hour, and normally operated at or below 3,000 feet. The V-1 was not controlled from an external source, having an internal gyro for stabilization and a compass for direction.



About 8,000 V-1s were launched against London of which 2,300 actually hit the target. Although the V-1 was unsuccessful in the desired accuracy and was very vulnerable to countermeasures, nevertheless, it was an extremely effective weapon when consideration is given to the amount of damage it did to property as well as to civilian morale.

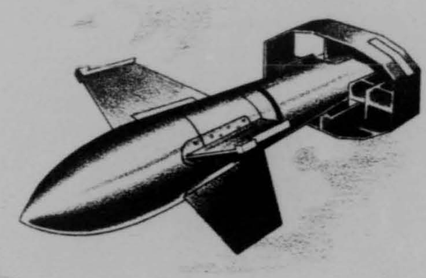
V-2

The V-2 was one of a series of ten rockets which had been under development by the Germans since 1929. It was a supersonic, cigar-shaped rocket, about 46 feet long and 6 feet in diameter. It reached a velocity of about 3500 miles per hour, had a range of about 200 miles, and a maximum altitude of 50 miles. The total weight of the rocket was about 14 tons. The missile was launched vertically and combined the action of a controlled missile with that of a free objectile, using all of its nine tons of fuel in the first sixty seconds of flight. In four seconds it reached an altitude of 2,000 feet when a time switch actuated a pitch control system which tilted the rocket to an angle of 47 degrees with the horizon. It then continued in straight flight along this path until it had reached the precomputed velocity required for it to hit the target. At this point the fuel was cut off and it became a free and uncontrolled body in space. When the rocket returned to the denser atmosphere it was slowed down to about 2,500 miles per hour by air friction.

About 2,000 V-2's were fired at London, of which 1050 hit the target area. The accuracy of the rocket has been estimated at about 1 per cent of its range, i.e., at 200 miles range it would strike within two miles of its target. This limitation, however, was probably not nearly as important as the large amount of effort required to deliver one ton of explosive. However, when one considers that the V-2 was one of a progressive series of rockets with the ultimate design, the A-10, planed for launching against New York in 1946, its potentialities are certainly worth consideration, especially since there is evidence that the Germans intended to use an atomic warhead in the A-10.

Fritz-X

The Fritz-X was a 3,000 lb. armor-piercing, air-launched, high-angle, guided bomb. Designed for either wire or radio control, it was used in the Mediterranean where it sank the Italian battleship "Roma."



HS-293

The HS-293 was an air-launched, rocket-assisted, radio-controlled, glide bomb. It attained a speed of 375 miles per hour and had a range of 5½ miles. Some success was experienced with the bomb against shipping in the Mediterranean.

In addition to the missiles mentioned above, there were three weapons which were developed by the Germans but not put into operational use before the end of the war:

Schmetterling

The Schmetterling was a rocket-propelled, radio-controlled missile designed to be launched from the ground against our bomber formations.

Wasserfall

The Wasserfall was a surface-to-air missile, somewhat similar to the V-2 although smaller, with four control wings. It was guided to the bomber formations by radar tracking.

Enzian

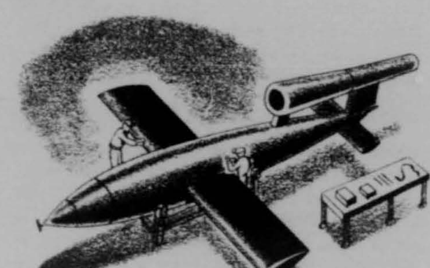
The Enzian was a surface-to-air missile, liquid-rocket propelled, and radio-controlled. It has a maximum speed of 600 miles per hour, and a slant range of about 15 miles.

Many people have referred to the German scientists as visionaries. However, they actually produced significant developments which placed German missiles years ahead of the rest of the world. That they were forward thinking is evidenced by the fact that some of them were actually planning such things as satellite rockets and space observation platforms.

SECTION III - MISSILE GUIDANCE

1. GENERAL

One of the most important problems connected with the development of guided missiles is that of guidance. Of course, the ultimate objective in guidance is to devise a system which automatically will control the path of a missile so that it will have a high probability of scoring lethal damage on a target in all combat situations. In general, guidance and control furnish the directive brain and nervous system for control of the missile under all conditions of flight. The technical problems in guidance and control of a missile are substantial; essentially the same performance is required of the missile as is now obtained from a fully-manned B-29, namely, reaching out long distances, locating a target, and then destroying it. However, one must add to this problem the perfection of a system able to handle both stationary and moving targets; a system that can handle more than one missile at a time, with freedom from enemy jamming, and above all, a system having accuracy at the distant



JB-2

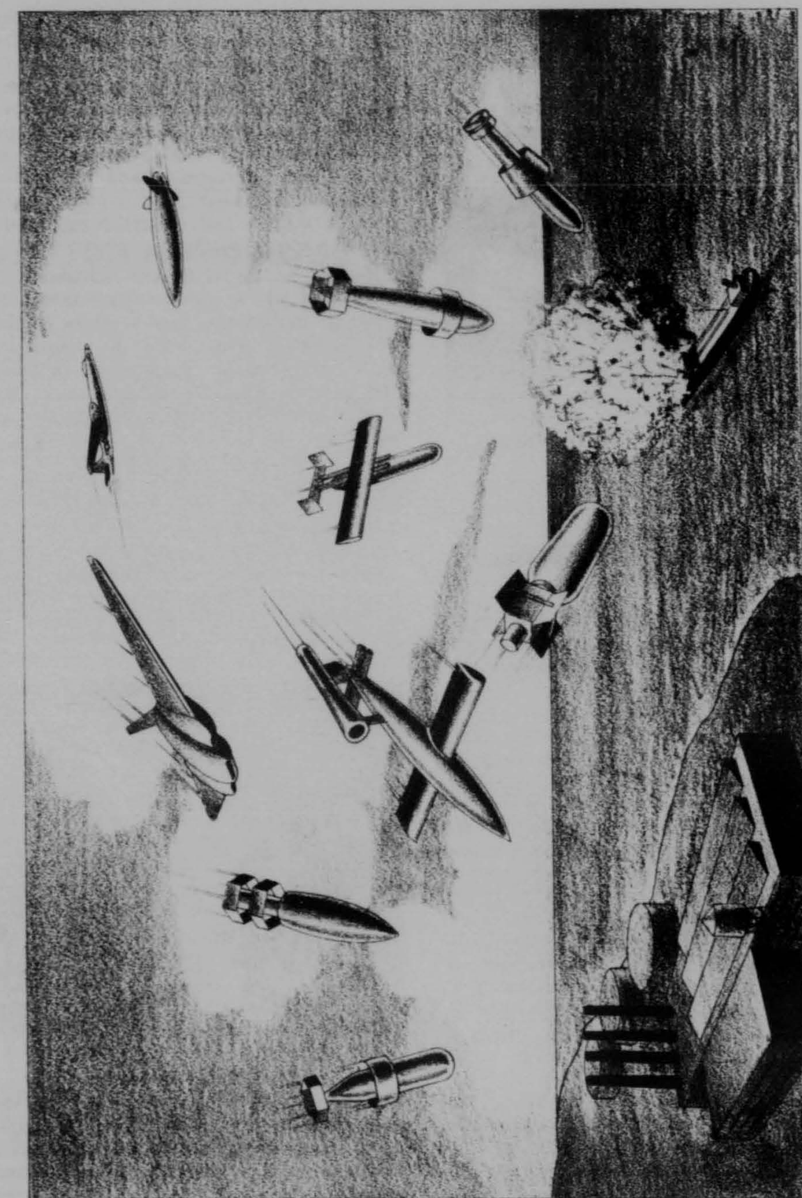


Figure 3-2 Guided Missiles Chart

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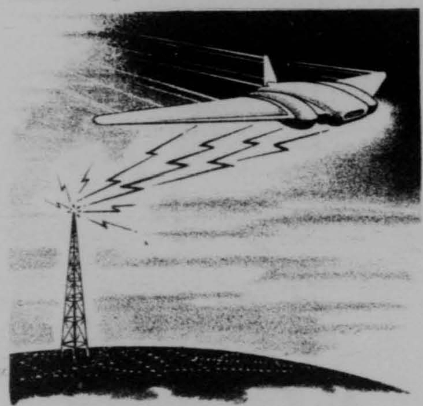
point of impact equivalent to that of artillery fire.

There are a great variety of possible guidance systems. The basic ones are: Preset Guidance; Course Seeker Guidance; Command Guidance; Homing or Target Seeker Guidance.



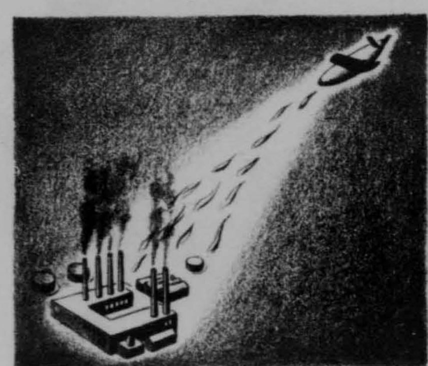
Preset Guidance is that in which the missile may follow a course which is completely determined before the missile leaves the ground.

Preset control has certain advantages in that it is self-contained and self-directed. The control system is free from countermeasures and interference and the missile can be flown along paths and at altitudes for which the fuel requirements are low. Nevertheless, the system has its shortcomings. Its accuracy decreases with the increase in range, there is a low probability of hits with a single missile except in area targets, and it is not effective against moving targets.

Course Seeker Guidance makes use of radio aids to navigation, and triangulation, to determine the constant exact position of the missile; the missile is directed along a radio beam. This latter method is called beam rider. In this system, the accuracy decreases with range, but the ability to handle a large volume of traffic is a definite advantage.

Command Guidance is a system in which equipment is provided for determining the present position of both the target and the missile. Then signals are transmitted to the missile to guide it along the desired course to the target. Command Guidance is the most flexible of all guiding systems since it provides directive control of the missile along the desired course. Its disadvantages are its susceptibility to jamming and its limited traffic-handling capacity since each missile must be tracked and controlled separately from the control station.

Homing or Target Seeker Guidance. All methods of missile guidance have the characteristic of becoming less accurate as the missile moves away from the source of control information. The ultimate in guidance accuracy would be realized if the source of such control information were located at the target itself. A homing system is one which makes use of some feature of the target to cause the missile to be directed toward that target. Radar, radio transmission, and infrared have been proposed for use in homing guidance. (The Germans were developing a sonic means at the end of the war.) Three types of target seeking devices are built in to the missile to increase the accuracy in the last stages of flight.



The automatic Radar Seeker is merely an extension of the fire control radar with the controls extended to the missile controls. Because good radar definition is required, a radar seeker is satisfactory for isolated targets such as ships and aircraft, but it is not

much use against normal ground targets.

Light and heat seekers are dependent upon the light or heat differential between the target and the surrounding area. These are best for targets of opportunity. A type of seeker in this same category is a **radiation seeker** which is sensitive to radioactive targets such as atomic piles and atomic bomb plants.

Radio seekers would home on enemy radio stations or small beacons planted by friendly agents.

SECTION IV - ORGANIZATION

1. GENERAL

Evidence of the great importance attached to the guided missile program by our national planners may be found in the study of the organization set up to control the development of the program.

The coordinating agency on the top level is the National Research and Development Board. Perhaps the most interesting result of this coordination is the policy concerning operational responsibilities: which particular service will operate the various types of missiles. The Army and Air Force agreement of 15 September 1947 provided, in general, that: tactical surface-to-surface missiles which have a direct effect upon the current Army tactical operations are assigned to the Army; surface-to-surface missiles which do not directly affect current battlefield operations, but which are suitable for strategic bombardment, are assigned to the Air Force; surface-to-air security missiles (battlefield defense missiles) will be assigned to the Army, while those employed in area air defense will be assigned to the Air Force. The Air Force will also operate air-to-air and air-to-surface guided missiles.

A second organizational unit is the Air Coordinating Committee of which a subcommittee concerns itself with guided missiles. This organization considers all air matters pertaining jointly to the Air Force, Navy, Army, National Advisory Committee for Aeronautics, etc.

Staff Organization. Within the staff structure of the Headquarters, United States Air Force, are two offices primarily dealing with the guided missiles program. Under the Deputy Chief of Staff, Operations, there is a Guided Missiles Group charged primarily with requirements, organization, training, and operations. Under the Director of Research and Development, Deputy Chief of Staff, Material, there is a Guided Missiles Branch charged primarily with formulating a guided missiles research and development program.

Command Organization. Within the command structure of the USAF, the Air Materiel Command is the agency responsible for the execution of research and development. Holloman Air Force Base, adjacent to the Ordnance White Sands Proving Ground, is the main AMC testing facility for guided missiles, while the 1st Experimental Guided Missiles Group, a flying unit, is concerned with the service tests and determination of tactics and techniques for guided missile use.

SECTION V - SUMMARY

GENERAL

This chapter on guided missiles can best be summarized by a brief resume of Air Force requirements for guided missiles. Since requirements precede developments, such a resume will also afford a glimpse as to the future course of missile development.

Included in all of the military characteristics lists are performance requirements listed in the order of operational priority.

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Of high priority on all lists are accuracy and speed. We must have accuracy or guided missiles will never be used operationally because of their inherent high cost in money, material, and manpower. Speed is very important because it is in speed that guided missiles will find the invulnerability which is so promising.

In the air-to-air category, the operational requirements for adequate defense of bombardment aircraft and for increase in firepower for fighter aircraft have indicated a high place on the list for air-to-air missiles. Against air targets, accuracy and warhead requirements are interdependent. In general, it is felt that one out of two missiles must be placed close to the target and the warhead must make a positive kill when so positioned.

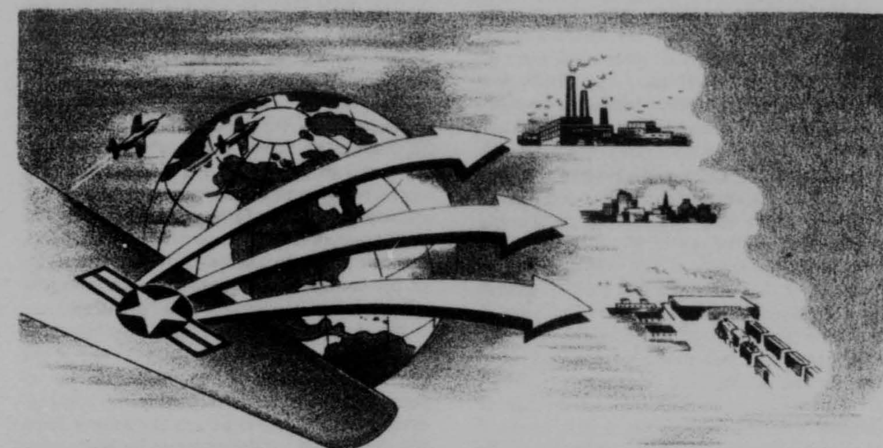
The demand for improved accuracy and effect in air-to-surface bombing, plus the desire to keep the bombers outside the range of ground defenses, has led to the establishment of requirements for air-to-surface guided missiles to supplement, and possibly replace, conventional bombs.

The requirement for the defense of both military and industrial installations against guided missiles and bombardment aircraft has resulted in the formulation of military characteristics for surface-to-air guided missiles.

The desirability of increasing the offensive bombardment power of the Air Force has made full investigation of surface-to-surface missiles advisable. The ability of the surface-to-surface missile to operate equally as well under all conditions of weather, defense, and range makes it the "ideal weapon," the weapon which military leaders have desired since the days of the sling and the bow. It ultimately represents all that could be required in range and destruction.

When these requirements are studied in relation to accomplishments, one finds that the art of the design and operation of guided missiles is still in its early stages. It may be stated with confidence that a war fought primarily with guided missiles is not a technical possibility within the next few years whether it be carried on by the United States or by any other great power. American technicians feel that America is as far advanced, if not further, than any other nation. But, in spite of this, pushbutton warfare is not just around the corner as many people seem to believe.

CHAPTER 4 - AIR DOCTRINE



SECTION I - DEVELOPMENT OF AIR DOCTRINE

1. HISTORY

P-1-7

The military doctrine of the use of the airplane as a weapon has been undergoing a gradual evolution since the days of the first heavier-than-air craft. It has been an uphill fight all the way, characterized by publicity, bitterness, and recrimination. The great debate over air power has revolved around the acceptance of a fundamental doctrine that the airplane possesses such flexibility and such advantages of speed and altitude as to enable it to destroy all surface installations.

If the accuracy of that doctrine is conceded, the predominance of the role of the Air Force in the national military establishment and the necessity of planning all campaigns to insure the most advantageous conditions for our air power seems logical. The protracted controversies over the relationship of the air force to surface forces in a military organization has been reflected in the struggle of the advocates of air power to free it from the organizational and operational confines of surface command. The difference of opinion between the most zealous adherents of air power and the most stubborn and dogmatic of the skeptics has not been over theories of strategic or tactical employment of the available weapons; it has revolved about the fundamental power of a particular weapon.

The advocacy of air power as the predominant instrument of war gained in force when it came from men who had been subjected to the tests of actual warfare. World War I brought to the fore two men who remained the leading protagonists of the doctrine of the supremacy of aircraft. For a dozen years thereafter their writings played a large part in the evolution from a simple faith in that doctrine to its use as the basis for theories of employment of forces and selection of objectives.

These two men, Guilio Douhet and William Mitchell, led lives that were strikingly parallel. Both entered the army in youth. Both possessed an imagination which led them to seek employment in connection with the promotion of other mechanical novelties in the military service before they were attracted to aviation. Both became severely critical of the military leadership of their time and suffered punishment in military courts for their criticism and the manner of its expression. Both were fluent and appealing writers; Mitchell addressed himself, in his published writings, primarily to persuading the public, while Douhet wrote more specifically for a professional, military audience.

Douhet. Guilio Douhet was born in 1869 and died in 1930. He entered the Italian Army as an artillery officer and first wrote of the importance of air power in 1909. By 1915, he had already conceived the image of total war and of that shattering of civilian morale by air attack which played a large part in the later evolution of his thought. He also advocated the "destruction of nations" from the air as a military measure. In 1916, after he had sent to a member of the Italian cabinet certain memoranda highly critical of the existing policy of the Italian staff, he was court-martialed and sentenced to a year of imprisonment. The decision of the court was formally repudiated in 1920. In the meantime, he had been recalled to service and placed at the head of the Central Aeronautical Bureau. Douhet attained the rank of General in 1921, the year from which his first serious writings on air power date. He was designated commissioner of aviation immediately after the Fascist march on Rome, but he withdrew from the government to concentrate on the literary advocacy of his views.

There are two major assumptions underlying Douhet's theories of air power. One assumes that aircraft are instruments of offense with incomparable potentialities against which no effective defense can be foreseen. The other assumes that civilian morale will be shattered by bombardment of centers of population. It was on this foundation that he proposed his doctrine, the essential elements of which may be paraphrased as follows:

To assure an adequate national defense, it is necessary and sufficient to be in a position to gain command of the air.

The primary objectives of aerial attack should not be the military installations alone, but industries and centers of population remote from the contact of surface armies.

An enemy air force, in particular, should not be dealt with by combat in the air, but primarily by destruction of the ground installations and of the factories from which its supplies come.

The role of surface forces should be a defensive one, designed to hold a front and to prevent an enemy advance along the surface, and in particular, an enemy seizure by surface action of one's own communications, industries, and air force establishments. The development of one's own aerial offensive, meanwhile, is proceeding with its paralysis of the enemy's capacity to maintain an army and the enemy people's will to endure.

Of the correctness of the first of these conclusions there can be little doubt, if the phrase "command of the air" is to be interpreted in a very strict sense. If a belligerent state is able to attack the enemy from the air at will, all defense having been liquidated, the victory of the nation having the free use of air power is inevitable. The conclusion is sound, but the primary difficulty arises in obtaining the necessary command of the air.

It was in his insistence upon the second of his basic conclusions, the preference of the industrial over the military objective, that Douhet most closely anticipated future strategy. The importance of the industrial objective has grown with the passage of time.

Perhaps one of Douhet's more faulty reasonings was his belief in the effect aerial bombardment would have upon civilian morale. The events of the past war have not borne out his contention that the people would break under such an attack. However, it should be remembered that he was thinking in terms of a saturation attack made after all opposition had been reduced. Perhaps, with the atomic bomb, his ideas along this line eventually may be proved to be correct.

Although Douhet's writings give surface forces an explicit function in defensively holding a surface line, (a corresponding role was contemplated for naval forces), the implication is strong that, with proper development in the use of air power, the progress

of events would be so swift that only a comparatively short delaying action would be needed before the issue had been otherwise decided.

In addition to his specific conclusions as to how a campaign should be conducted so as to make use of the overwhelming power of an air force, Douhet had ideas on military organization and general policy. He was an unrelenting advocate of the unification of the military, naval, and air organizations. He stated that there were theories of land war, naval war, and air war; that these theories exist, evolve, and develop, but that a theory of war—total war—was almost unknown. Therefore, he advocated the organization of national defense through a central ministry, and in 1927, such an organization was created in Rome.

The influence of Douhet's writings has been far-reaching. Much of what he said has been supported by experience. Much, on the other hand, has proven either over-optimistic or specifically erroneous. Some of his beliefs were proved unsound during the past war; yet the trend in development has, in most respects, been in the direction that Douhet foresaw. He went far astray in his specifications as to the characteristics of the aircraft that would be used in future wars. However, his judgment of the ways in which they should be used is more nearly valid now than it could have been under conditions existing during his lifetime. Further development is likely to bring the strategy and tactics of air power still closer to the practices advocated by Douhet.

Michell. General William Mitchell's activities were contemporaneous with Douhet's. The conventional assignment of Douhet's name rather than Mitchell's to much of their common belief is due in part to chance, in part to Douhet's clearer and more systematic literary development of his conclusions, and partly to the livelier interest in military studies in Europe as compared with that in the United States.

Mitchell shared in some degree, although without Douhet's complete confidence, the conviction of the prime efficiency of attack upon the enemy's economic and industrial structure. He shared the belief in the comparative fragility of civilian morale. Like Douhet, he believed in the possibility of paralyzing civilian and industrial activities through a relatively modest volume of bombardment. He stated that the advent of air power, which can go straight to the vital centers and either neutralize or destroy them, had put a completely new complexion on the old system of making war. It was now realized that the hostile main army in the field is a false objective and that the real objective is the vital centers. The result of warfare in the air would be to bring about quick decisions. Superior air power would cause such havoc, or the threat of such havoc, that a long drawn out campaign would be impossible.

In Mitchell's first writings after 1918, he gave much attention to the collaboration of air with surface forces. But, as time passed, surface forces receded more and more into a secondary position in his estimation and his confidence in the technical capacities of the airplane grew. He continued, however, to attach a great importance to the use of air power for the destruction of enemy surface forces. In this respect, he differed from Douhet who virtually was willing to ignore the surface forces while destroying the nation and the resources behind them. The difference was partly a reflection of the difference in nationality and in the geographical outlook of the two men.

Many American advocates of air power as the primary element in our military organization have written of the defense of the continental United States as our primary military concern. Mitchell never accepted any such limitations. He was the first to discuss the application of air power—with a minimum of support by surface forces—in global terms. He was a tireless advocate of the Arctic air routes between the continents. He dwelt endlessly upon the value of a trans-Atlantic route by way of Greenland and Iceland and its feasibility for military use; he pointed to the corresponding value and feasibility of aircraft movement between the United States and Asia by way of Alaska and Siberia, or by the Aleutian and Kurile Island chain. Very early in his military career he marked Alaska as the key to military supremacy of the

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Pacific.

As a military pilot personally experienced in the actual command of air forces in battle, General Mitchell was much more intimately acquainted than Douhet with tactical problems. He employed his talent to the full in the improvement of existing tactical methods. One of his most strikingly farsighted proposals was a plan for using parachute troops behind the enemy lines in 1918.

In matters relating to the technical characteristics of aircraft and to the details of their operation, Mitchell was incomparably more expert than Douhet. The intensity of his enthusiasm, however, led him on occasion to overestimate greatly the rate at which technical progress would be made in the near future.

Mitchell, as Douhet, favored the emancipation of the air force from the ground armies. He felt that only through an independent air force, controlled and operated by airmen, could the United States realize the full potential of air power. In the conflict which characterized the long struggle of the air force to achieve independent status, Mitchell wrote and spoke as an intense partisan, becoming more and more impatient with opposition and increasingly disposed to denounce it as stupidly reactionary, blinded by self interest, and dishonesty.

As a result of the manner in which he presented his views, he was, as was Douhet, court-martialed and sentenced to reduction in rank for five years. Shortly, thereafter, he resigned from the Army.

Mitchell's doctrine of air power can be summed up by a statement he wrote in 1930: "War is the attempt of one nation to impress its will upon another nation by force after all other means have failed. The attempt of one combatant, therefore, is to so control the vital centers of the other that it will be powerless to defend itself. The advent of air power which can go to the vital centers and entirely neutralize or destroy them has put a completely new complexion on the old system of war. It is now realized that the hostile main army in the field is a false objective and the real objectives are the vital centers. The old theory that victory meant the destruction of the hostile main army is untenable. Armies themselves can be disregarded by air power if a rapid strike is made against the opposing centers."

Many of his predictions have come true. Others will be realized in years to come. However, many of the technical developments which seemed to him to be on the horizon are still far from being in practical use. General Mitchell was immensely imaginative, both in technical matters and in tactical ones. It was even more true of him than of Douhet that he characteristically foresaw the direction in which progress would be made, but was often oversanguine about its rapidity.

Seversky. Alexander de Seversky was a Russian military pilot during the first World War and, subsequently, an inventor, airplane designer, and author. He has consolidated his views on air power, its potentialities, and the defects in its present use in his book, "Victory Through Air Power."

Although his views, in large part, follow those of Mitchell, the outstanding feature, which characterizes him above all the other students of the subject, is the insistence upon the vital importance of a large radius of action. He emancipates the air force of the future from concern with extensive ground supporting organizations and from dependence upon the air bases of the Arctic routes in the Atlantic and Pacific to which Mitchell attached such great importance. He maintained in his book that: "It is sheer waste to maintain advanced bases instead of hurling the full aerial potential directly against the adversary. The entire logic of aerial warfare makes it certain that ultimately war in the skies will be conducted from the home grounds, with everything in between turned into a no-man's land."

The advocates of air power have been the object of constant attack by conservative critics on the grounds that they propose to win wars with imaginary instruments and that they reach their conclusions by endowing aircraft with potentialities far exceeding those actually available. Against Douhet the charge has only a very limited pertinence; against Mitchell much more validity; and against Seversky even greater validity.

Since World War II, Douhet has been in

the background probably because some of the points of his theory have not been borne out. However, in the light of the present day potential the modern air weapon comes closer to fulfilling Douhet's expectations than did the aircraft of World War I. Furthermore, Douhet, were he writing today, would have seized upon the atomic bomb as the ideal instrument of air power.

Looking at the writings of Douhet from a broader viewpoint, we see that his theory not only embraces the entire subject of aerial warfare but also encroaches on that of war in general. It predicts that air action will have a decisive effect on the outcome of future wars; it also recommends that the three branches of the armed forces of a nation be co-equal under a single directive head and proposes that in allotment of funds the air arm receive the preponderance.

Military analysts have pointed out many things we have learned about air power in World War II. The overwhelming majority realized that air power had been too long bound to the army and that it should be established as co-equal to the ground and sea forces. This was accomplished by the National Security Act of 1947. It is interesting to note that, in spite of the belief that this was a new and a bold move, an almost identical act had been presented to Congress in 1923 and, furthermore, this act followed almost to a letter the original pronouncement made by Douhet.

Today the three long sought after goals of American air power have come into being. There exists an independent air force; there is in existence a tried and sound doctrine for the global use of strategic air power; and the long range air weapon to accomplish this mission is in sight.

SECTION II - STRATEGIC AIR POWER

1. GENERAL

Air power has been defined by the Air University as the **"total aviation capacity of a nation-civilian and military, commercial and**

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private, potential as well as existing." An air force, then, may be considered as the military component of air power. This section deals with the application and employment of an air force in a strategic role.

Prior to World War II, there were two types of decisive military action. First, a ground army could defeat a hostile ground army and, subsequently, defeat the enemy nation. Second, a navy could strangle an enemy nation by controlling the sea lanes of communication and, thereby, cause capitulation of the enemy. During World War II, a third category of decisive military action was developed. That category is air action. It was shown during the war that air power applied directly against the vital points of the enemy's national structure can cause the defeat of that nation.

During the period 1939-1942 the Germans were overrunning Europe; their successes were dazzling and ominous. The question in everyone's mind was, "How can we stop the German blitzkrieg?" The answer was not readily apparent. It was arrived at through the perseverance and foresight of the Allied air leaders. They saw the strategic possibilities of air warfare. It was not easy for our air leaders to support a strategic concept on the use of air power when the Germans were achieving outstanding success with their air arm tied to surface action.

It was not until 1943, at the Casablanca Conference, that the strategic concept of the use of air power was given an official blessing. This conference resulted in the definition of strategic air operations as we think of it today. **Strategic air operations are air operations aimed at the destruction and dislocation of the enemy's military, industrial, economic and political system and the undermining of the morale of the enemy's people to the point where his capacity for armed resistance is fatally weakened.** This definition is the very core of the present day doctrine of strategic air power.

2. MISSIONS OF A STRATEGIC AIR FORCE

The primary mission of a strategic air force is the implementation of the concept that air power effectively employed against the vital points of an enemy's national structure can be decisive in a war. More specifically, the primary mission of a strategic air force is the destruction and/or neutralization of assigned objectives within an enemy controlled area. This means that the strategic air force will train and prepare to destroy or neutralize industrial targets, transportation targets, armament targets, or any system of specific targets which permit an enemy to conduct war.

It should be realized that in the future it may be highly desirable to deny certain areas to the enemy without destroying those areas, in order that existing installations may be used again. Under such circumstances the mission becomes neutralization rather than destruction, e.g., aerial mining of a harbor rather than the destruction of port facilities.

In World War II, the accomplishment of this primary mission was not possible until the attacking strategic air forces had gained air superiority in their areas of operations to such a degree that penetration to strategic targets could be made within the limits of acceptable losses. Thus, the gaining of air superiority was a prerequisite mission which was actually a part of the primary mission. It should be emphasized that this prerequisite mission was the means to an end. The end was the capability of penetration. In future wars we may achieve penetration by surprise, speed, the cover of darkness, or bad weather, or by special technological advances. Thus, in a future war, we may be satisfied to attain momentary air superiority by these means rather than fighting for the control of the sky as we did in World War II.

The strategic air force may, of course, be assigned other missions than the primary one, if and when the situation warrants it. One mission in this category is direct cooperation with the surface forces. In this case, the strategic air force reverts to the role of a tactical air force. Two outstanding examples of this type of mission were the utilization of the Eighth Air Force in direct support of the Normandy invasion and the diversion of the Twentieth Air Force to bomb airfields in Kyushu in support of the Okinawa invasion. The strategic air force might also

be given such missions as air supply, search and rescue, or simply training for a future mission. All these missions, however, are subsidiary to the primary mission of a strategic air force.

There should be little doubt as to the normal priority of the missions assigned to a strategic air force. If we truly advocate the concept that air power properly employed against the vital points of an enemy's national structure can be decisive, then relentless prosecution of the primary mission should be the objective of the strategic air force. It is designed as a tool to be used to destroy or neutralize an enemy's means and will to carry on a war. A strategic air force wins wars by progressive destruction or neutralization of an enemy's vital targets, thereby, denying to an enemy the ability to maintain an armed force. It is, therefore, the objective of a strategic air force to win wars, not battles. Such a concept calls for extreme caution before any attempt is made to divert a strategic air force from its primary missions to secondary ones.

3. TYPES OF STRATEGIC AIR OPERATIONS

The accomplishment of the primary and subsidiary missions of a strategic air force requires the employment of many different types of strategic air operations. The choice of the types to be employed in any given place at any given time will, of course, depend upon the nature of the situation and the current objectives.

Bombardment. The main type of air operation performed by a strategic air force is bombardment. Bombardment includes bomber and fighter operations, the purpose of which is to destroy or neutralize. The bomber aircraft is today the main carrier of destructive force employed by the strategic air force and will probably continue to be so until better agents are developed. This is true despite the disadvantage of bomber aircraft. These include its vulnerability to antiaircraft fire, its need for fighter escort for deep daylight penetrations, and the fact that it is still somewhat subservient to weather. The escort fighter is a major problem at present because of its range. Certainly, the escort fighter is mandatory at present if bomber operations are to be conducted in daylight. Bombardment operations, employing both bomber and fighter aircraft, are consequently the most important type of strategic air operations.

Aerial Mine Laying. A second type of strategic air operation is aerial mine laying. This type of operation proved very effective against Britain, Japan, and to a lesser degree against Germany in World War II. It is a highly effective and amazingly efficient means of throttling waterborne commerce. It should be considered as a weapon in any air attack against a nation which relies upon water transportation to support an important part of its economy.

Strategic Reconnaissance. A very important air operation which is performed by a strategic air force and which augments and supports the main strategic bombing and mining campaign is strategic reconnaissance. Reconnaissance is the life blood of the strategic air operations, and can be subdivided into photo, weather, radar, and radar counter-measure phases.

Propaganda. The strategic air forces, because of its tremendous destructive potential, may be employed to great advantage as an agent of psychological warfare. This can be done by two kinds of propaganda operations: 1) mass demonstration flights designed to impress the opposition, and 2) leaflet drops and similar operations, the purpose of which is to put propaganda material into the hands—and ultimately into the minds—of the enemy people in order to weaken their will to resist. The strategic air force probably would be directed to fly propaganda missions when it can be expected to be more effective than the actual application of force.

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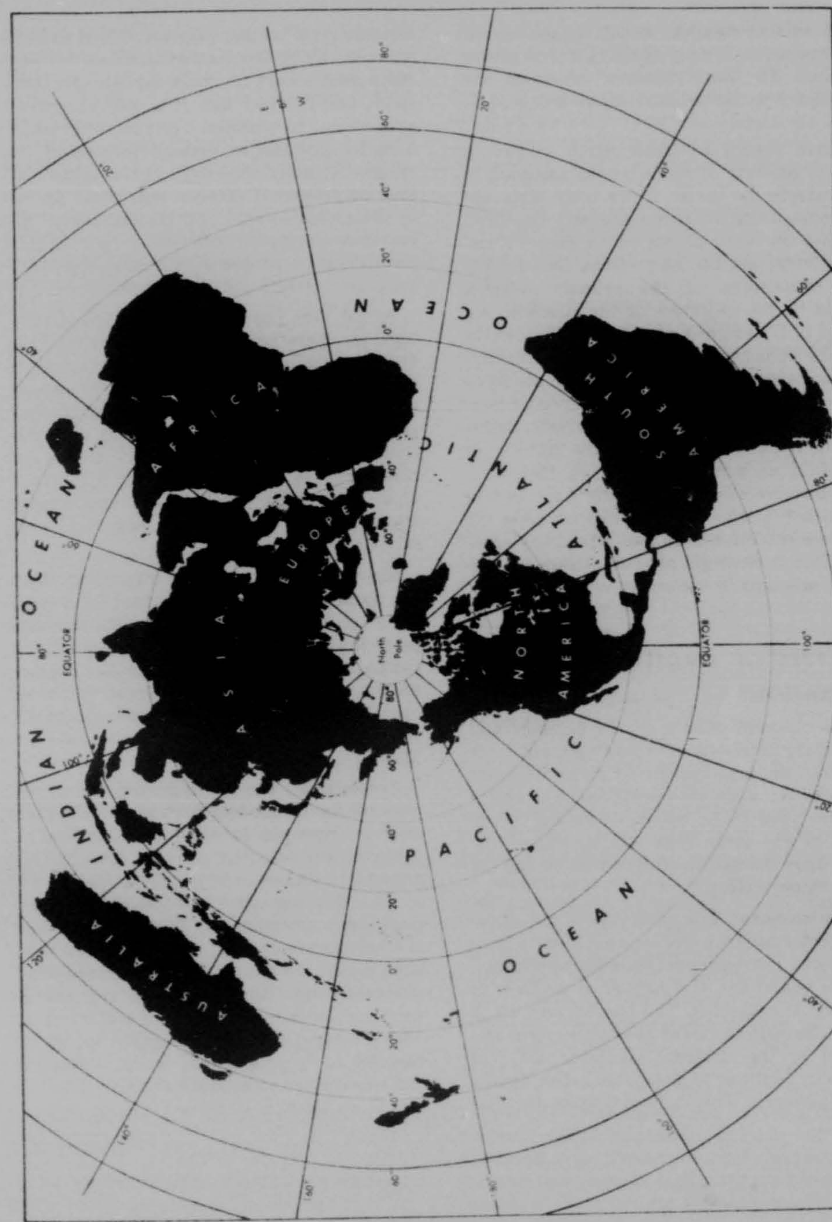
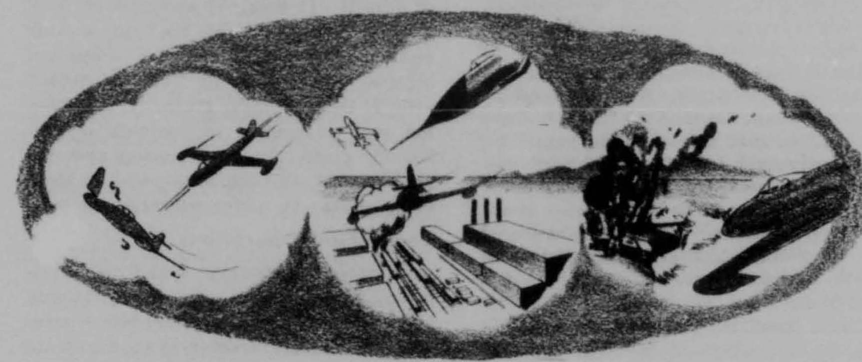


Figure 4-1 The World Showing Radius of Action of B-36 (5000 Miles) (Scale 0 —— 5000 miles)

SECTION III - TACTICAL AIR POWER



1. GENERAL

Until World War II, military aviation had been used almost entirely for tactical operations. As lighter-than-air balloons were developed and, much later, airplanes, professional fighting men considered their use in the light of how they might benefit the army or navy. Although air operations brought some innovations in details of warfare, neither the generals nor the admirals altered their opinions of how to conduct a campaign until almost 150 years had elapsed after the first balloons were used by a military force.

Observation, the first function of military airmen, remained the principal activity for many years. In the middle of the nineteenth century an attempt was made to bomb an enemy with explosives carried by a balloon, and during the Civil War artillery spotting was done from balloons. The airplane entered the picture at the turn of the century and saw considerable service in World War I. The pattern of air operations changed but little, however, and observing the enemy remained aviation's major role. The attempt to prevent observation from airplanes introduced air combat. Aircraft weapons and antiaircraft weapons were soon developed and inevitably attacks were made upon ground personnel.

In recent wars, the theory of tactical operations has progressed somewhat. The Russians, Germans, and Italians who participated in the Spanish Civil War made some small gains, but the primary purpose of air operations was still to pave the way for the infantry and to interfere with supply and reinforcement. In World War II Germany misapplied her air power in a way that has become almost a classic example. Already possessing the world's greatest air force and a high degree of air superiority, Germany permitted its air units to remain tied to its ground armies. The necessity of maintaining air superiority was ignored. Although Germany opened World War II in a most logical manner by immediately destroying the Polish Air Force, the thinking of the German high command slipped back to the principle of subordinating air to ground forces.

Thus, for over a century the obviously apparent need for efficient tactical air operations had been misunderstood. Although air forces had, in the main, been used in a tactical role, the early phases of World War II showed no clear-cut concept of tactical air operations, nor were the air units organized, equipped, or trained for the specialized tactical tasks.

The current concept of tactical air power was evolved during the North African campaigns of 1940-1942. In June 1940, the RAF opposed a large, powerful, and modern Italian air force in Libya. Italian air units were dispersed among local army commanders and operated under the direct command of the Italian ground forces. The RAF, operating en masse as an independent air command, not only held its own but eventually destroyed the numerically superior Italian air force.

The German air force replaced the Italians and the fight for North Africa continued for two more years. Units of the USAAF joined the RAF in 1942 and the Allies gained air superiority and held it. The Allied Northwest African Tactical Air Force, formed from British and American units, was placed under one commander. The organization of this air force, which gained its victory in North Africa, became the prototype of a tactical air force organization.

The theories, for employing air forces in joint warfare, which evolved from the North African campaign became accepted principles. In North Africa was realized the cardinal fact of tactical air power; that the air forces available should be concentrated under one air commander who will work with the ground commander toward the same objectives. These theories were published in 1943 in FM 100-20 "Command and Employment of Air Power." This FM established three phases of tactical air operations as official doctrine. By the time World War II had ended, many modifications in techniques and organization had improved tactical air operations, but these general rules survived and are applicable today: a) a tactical air force should be organized specifically for tactical operations; b) associated air and ground commanders must almost literally live, eat, and work together; c) air superiority is a prerequisite before tactical air forces can operate with surface forces.

2. MISSION OF A TACTICAL AIR FORCE

It can be said that the wartime mission of tactical air power is to execute, either independently or jointly, sustained offensive and defensive operations aimed at the destruction or neutralization of a critical enemy military force together with its immediate reserves and supplies.

The operations of a tactical air force consist of three phases in the following order of priority: 1) Establish and maintain local air superiority. 2) Isolate the battle area by restricting movements of enemy troops and supplies into, within, or from the combat area. 3) Destroy enemy ground forces within the zone of contact in conjunction with friendly ground forces. Depending upon the local tactical situation, some or all of these missions may be performed concurrently.

Counter-air Operations

Counter-air operations need little justification, particularly to an airman. Attaining air superiority can secure the "three freedoms" of warfare: freedom of the air for air operations, freedom of movement for surface forces, and freedom of flow of supplies. When one side has all three freedoms and the enemy has none, the stage is set for victory.

Air superiority is that degree of capability of one air force over another which permits it to conduct operations at a given time and place, without prohibitive interference from the opposing air force.

Air supremacy is that degree of air superiority held when an air force can maintain almost continuous air superiority in all combat areas. Securing air supremacy is a gradual process. It cannot be obtained in a single engagement. But once obtained, the victor should employ his air force so that air supremacy is never relinquished.

The true goal of counter-air operations is air supremacy and not merely air superiority or air defense in local areas. Securing air supremacy is probably beyond the capability of the tactical air arm because it requires not only that the enemy air force be permanently paralyzed but also that the enemy's air power be reduced through attacks upon its supporting structure. Effort expended in attempting to annihilate an enemy air force may not be economical in terms of results obtained.

Counter-air operations may be divided into two phases; offensive and defensive. Offensive operations consist of attacks on air craft

Strategic knocks out the enemies potential for war
Tactical stays with the ground forces (ground)

on the ground or in the air, airdromes, supply dumps, and any facility which directly supports the air arm. Air defense is the effort designed to oppose an enemy air attack. In its role of air defense in support of either a strategic air force or a surface force, the first requirement of the tactical air force is to prevent, if possible, and in any case interfere with the accuracy of enemy air attacks against personnel and installations.

Isolation of the battlefield, also called interdiction, disrupts the enemy's lines of communication. Forces in an area are cut off by interdicting, or disrupting, their means of traffic with other forces. This implies that nothing can move into, out of, or within the isolated area. Although in actual practice isolation is rarely total, complete separation should be the goal. Action should be taken against all traffic significant to the enemy's military operations. Railroads, highways, waterways, and airways with their facilities and the transport moving on them are important targets. Their destruction will stop the replacement or withdrawal of troops and the movement of supplies.

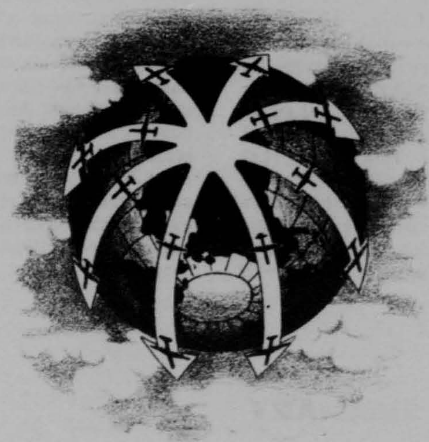
Cooperation with the surface forces completes the part that the air force plays in winning a ground war. With air and logistical superiority our ground forces are ready to exploit the situation. It is during this phase that the fighter-bomber becomes the most potent and flexible weapon of the tactical air arm. Fighter-bombers can knock out strong points and tanks, bomb and strafe front line troops and supplies, silence guns, and furnish air cover for armored columns by providing observation and additional firepower when critically needed by the tank commander.

SECTION IV - SUMMARY

The basic doctrine of the use of air power is a doctrine of strategic bombardment. It states simply that air power, properly employed against the vital points of an enemy's national structure, can be decisive. This is accomplished by strategic bombardment, i.e., air operations aimed at the destruction and dislocation of the enemy's military, industrial, economic, and political systems, and the undermining of the morale of the enemy's people to the point where his capacity for armed resistance is fatally weakened. The ultimate goal of American air power is the ability to conduct strategic operations over any target in the Northern Hemisphere from bases in the United States. We are today within striking distance of that goal.

Tactical air operations will play a role in air power whenever there is surface action or the threat of it. General Kurt Von Runstedt, one of Germany's outstanding commanders, states that the greatest single factor in the defeat of Germany was the effectiveness with which the Allies used air power. He did not say defeat resulted from the Allies having more and better airplanes and pilots. He attributed it to the manner in which they used what they had. The Allies organized for the job and developed equipment and methods for a particular task. Furthermore, they evolved a concept of tactical air employment and stuck to it. That the concepts which helped win the last war will change is to be expected. It may even be that in a future war the main job of a tactical air force will be to prevent a hostile force from engaging our surface forces in battle while the strategic air force carries out its assignment.

Whether it be strategic or tactical, the importance of air power cannot and must not be under-estimated. The words of the United States Strategic Bombing Survey (European War) bear this out: "The German experience suggests that even a first class military power—rugged and resilient as Germany was—cannot live long under full-scale and free exploitation of air weapons over the heart of its territory. By the beginning of 1945, before invasion of the homeland itself, Germany was reaching a state of helplessness. Her armament production was falling irretrievably, orderliness in effort was disappearing, and total disruption and disintegration were well along. Her armies were still in the field. But with the impending collapse of the supporting economy, the indications are convincing that they would have had to cease fighting—any effective fighting—within a few months."



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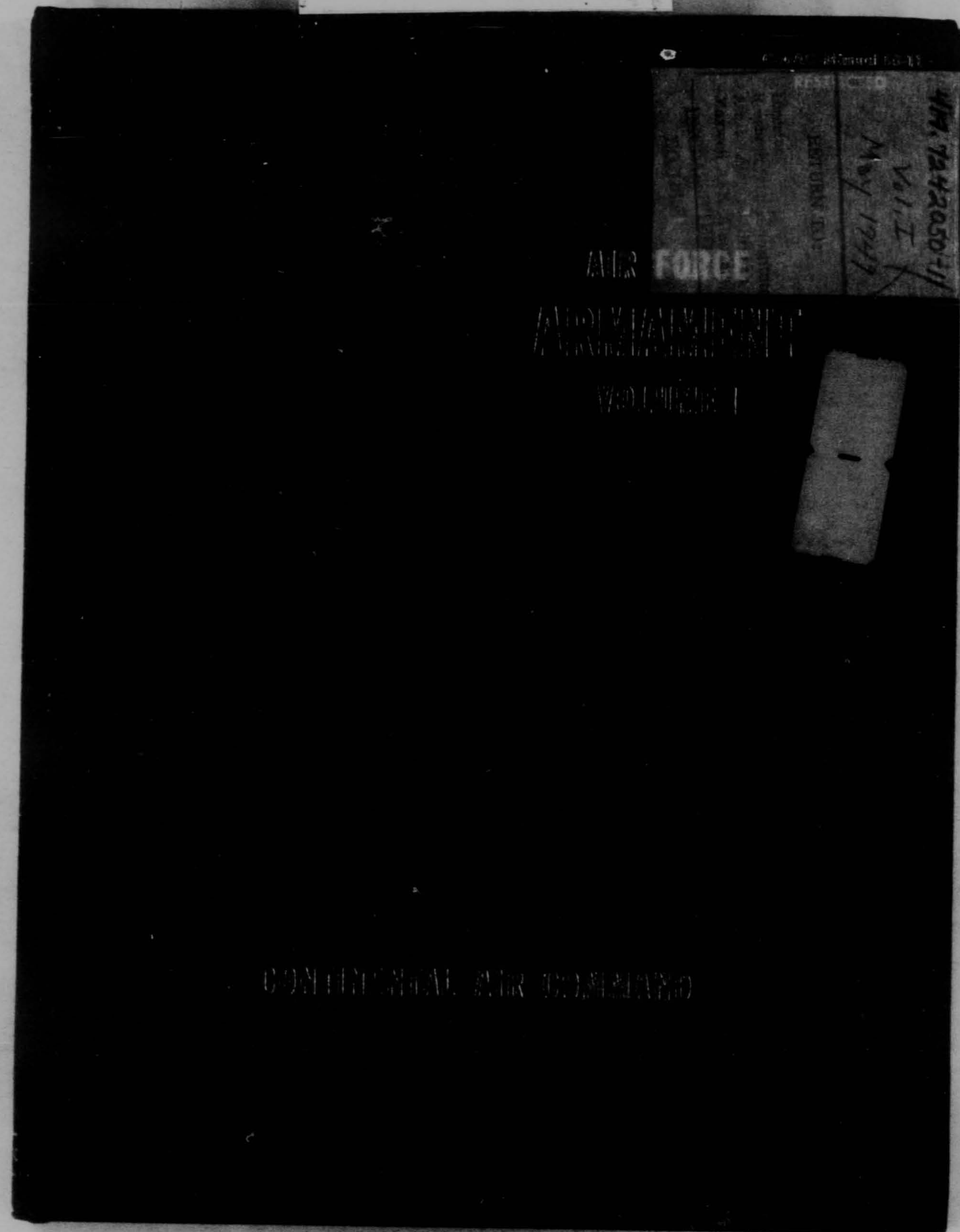
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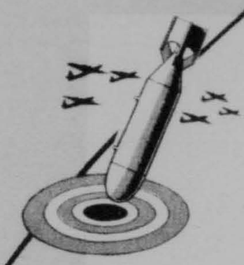

AIR FORCE ROTC

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CONTINENTAL AIR COMMAND

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Foreword

HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK
31 May 1949

ConAC Manual 50-11 Vol. I is published for the information and guidance of all concerned. It will be used in conjunction with the current program of instruction pertaining to Air Force ROTC Training.

BY COMMAND OF LIEUTENANT GENERAL WHITEHEAD:

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Major General, United States Air Force
Vice Commander

HEADQUARTERS OFFICIAL CONTINENTAL AIR COMMAND

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THIS MANUAL SUPERSEDES ConAC Manual 50-140-1, Vols. I, II, III.

Preface

THIS textbook has been prepared specifically for the college or university student who is participating in the Air Force ROTC program. It is one volume of a series designed to qualify him as an officer specialist in the United States Air Force.

The text is planned to indoctrinate the officer candidate in the fundamental principles of Air Force Armament, rather than to present a detailed treatise of the entire complex field.

In order to achieve maximum efficiency and effectiveness in the performance of his duties, the Air Force officer must be constantly aware of new developments in his specialty and its allied fields. A receptive mind, nurtured by supplementary research and reading, can be a vital force in the personal and professional development of the officer specialist throughout his career.

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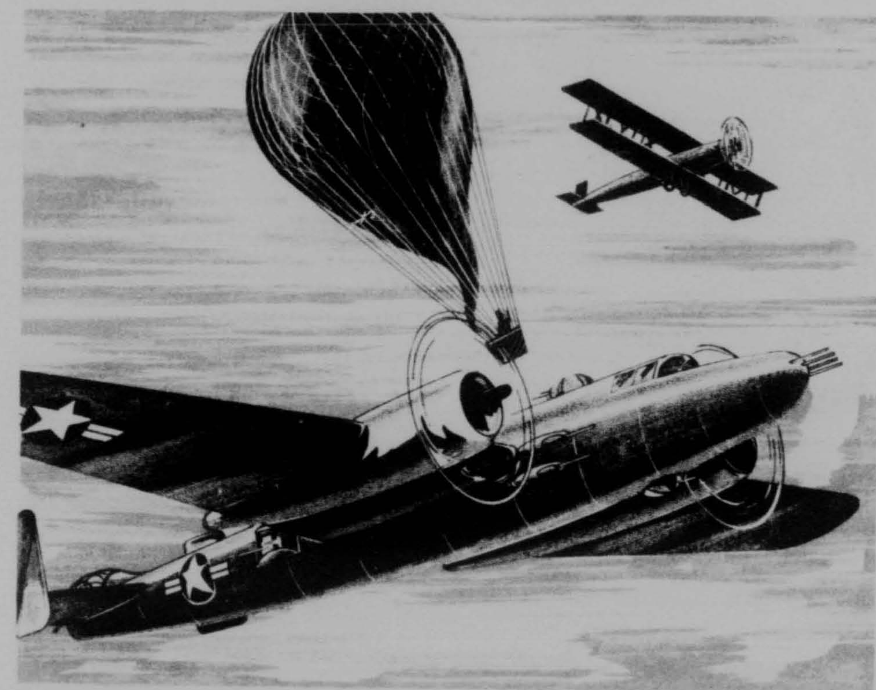
CHAPTER 1—HISTORY AND DEVELOPMENT OF ARMAMENT



SECTION I—FROM BALLOONS TO CONVENTIONAL AIRCRAFT

1. INTRODUCTION

The long span of centuries between mythical flight and recorded heavier-than-air flight was broken intermittently by the aeronauts (balloonists). First among these were the Montgofier brothers, who designed and built balloons capable of sustaining the weight of men in the air (1783).

The French were the first to employ balloons as an instrument of war. A large balloon, the "Entreprenant," was constructed and used successfully for observation purposes in the Franco-Austrian War. In 1794 it was used in the Battle of Fleurus.

The greatest disadvantage of the balloon as a means of military observation was that it could not be steered. Unless anchored, it drifted with the wind. Many attempts were made to provide devices to control the direction of flight, but to no avail. One of the most

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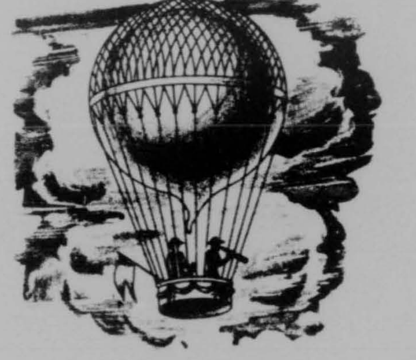

Entreprenant.

interesting ideas for making balloons steerable came from a staff officer of Napoleon's army during the Russian campaign (1814). This plan met with Napoleon's approval, and the first cigar-shaped gasbag made its appearance. The motive power consisted of several men who turned a large propeller by means of pedals. The speed attained, however, was a scant four miles an hour. Since that was insufficient to make headway against even a moderate wind, the man-powered dirigible was discarded.

In 1849 in a battle between the Austrians and Venetians, the Austrians found that the range of their batteries was too short to reach the city of Venice. When the wind was in the proper direction, blowing toward the city of Venice, the Austrians attached small bombs with time fuses to paper balloons. The balloons were capable of lifting the bombs to altitudes of thirty feet, and they drifted into the city. When well inside the city, the time fuses exploded the bombs. Although the material and physical damage which resulted was slight, the psychological effects were great.

In 1899, at the Hague Conference, an agreement was reached to prohibit the throwing of projectiles from balloons.

Nineteenth Century Progress

The nineteenth century was an age of rapid progress in engineering, yet it was frankly agnostic on the question of mechanical flight. This was the age in which the expression "might as well try to fly" had become a metaphor for the impossible. During this period there were men, daring and serious scientists, who refused to abandon the idea of flying. These men designed power-driven models and man-carrying gliders. In the closing period of the nineteenth century, three men were experimenting with power airplanes. These three men nearly succeeded.

Aviators

Orville and Wilbur Wright started their gliding experiments in 1900. Between 1900 and December 17, 1903, when power flight was achieved, the Wrights constructed the first wind tunnel; they made over one thousand glider flights and built an aircraft engine. The Wrights also devised two propellers which turned in opposite directions to eliminate torque.

It was not until Feb. 10, 1908 that the United States Government entered into a formal contract with the Wrights.

By 1910, military authorities of all the major powers had begun experimenting with airplanes. The airplane was regarded, however, as a more efficient means for gaining information in the field; its importance in dropping explosives in enemy territory was not yet considered seriously although in 1907, the restrictions of the Hague Conference were removed as far as bombing from the air was concerned.

The earliest recorded use of bombs dropped from airplanes was in 1912 by the Italians in Tripoli. These first bombs were converted from some other type of ammunition, probably artillery rounds.

First World War

The European, or First World War, started in 1914. Military aviation in Europe had developed much more rapidly than in the United States. At the start of this war, France and Germany each possessed about six hundred airplanes. They soon proved their worth in scouting and more and more reliance was placed on their work by the staffs of armies. Scouting soon changed to scouting and fighting. The opposing airmen began by firing at one another with sporting rifles and shotguns.

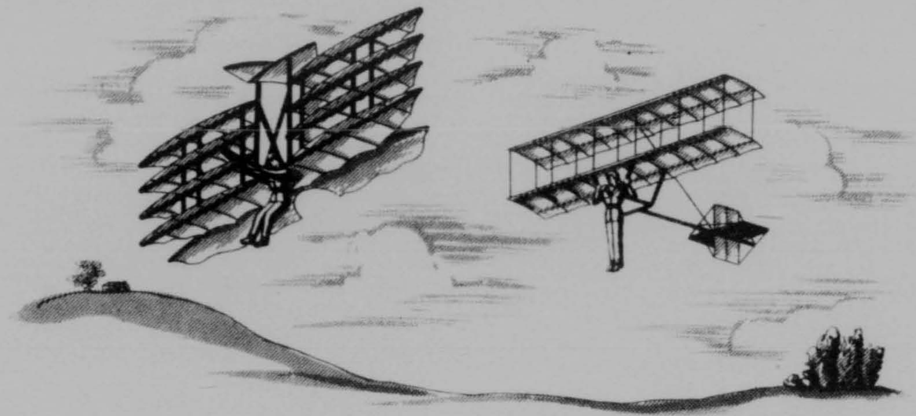

Figure 1–1. Chanute's Gliders.

Soon machine guns appeared, and then the Germans synchronized a machine gun firing between the blades of the rapidly-whirling propeller. By 1916, aerial fighting and bombing were being conducted on a grand scale. America's contribution was to ship overseas 740 airplanes, of which only 379 ever got to the front.

America's greatest aerial offensive did not get under way until the closing months of World War I. Under the American First Army, the greatest concentration of air power ever assembled during the war was massed for the September 1918 drive against St. Mihiel. A fleet of 1,481 planes, American, British, and French, under the command of Colonel "Billy" Mitchell, commenced a series of strategic attacks on German railway centers, communications, and troop concentrations.

On October 9, more than two hundred American bombers, accompanied by about one hundred pursuit craft and fifty-three 3-place planes, smashed a German counterattack by dropping twenty-two tons of bombs and knocking out a dozen enemy fighters. The bombs were released electrically from mounts underneath the fuselage. This was a decided improvement over the earlier bombing methods when bombardiers carried their bombs in a basket in the cockpit and tossed them overside by guesswork aiming.

Combat Statistics—World War I. Army air units, participating in 215 bombing raids, dropped over 255,000 pounds of explosives (on a single day in World War II the Air Force dropped approximately 10,000,000 pounds of bombs on Japanese installations alone); flew 35,000 hours over the lines; and took nearly 18,000 photographs of enemy positions. They regulated artillery fire, supported ground attacks, strafed and bombed enemy batteries, convoys, and troops.

Technical Developments

The United States did turn in a first-rate performance in the design and construction of the famous Liberty engine. The production rate was 150 a day. In addition to the Liberty engine, there were other outstanding technical developments during the World War I period. Some of these were: an oxygen mask equipped with telephone connections; wireless telephone with air-ground communications; electrically-heated clothing; automatic camera; helium gas; armored pilot seat; 8-machine gun ground strafing airplane, and great advances in aero-medical research.

SECTION II—AIRCRAFT ARMAMENT

1. GENERAL

Aircraft armament can be broken down into the following basic equipment:

Aircraft bombs and associated equipment
Aircraft machine guns
Aircraft cannons
Rockets
Cameras
Ammunition
Turrets
Gun sights

2. AIRCRAFT BOMBS

The prime requisite for military aircraft is to use their wide and highly-mobile striking power to drop bombs of various weights and for various purposes on enemy objectives. Bombs are manufactured in many different weight classifications because military conditions require attack on numerous objectives which require specific types of bombs.

Classification

Bombs may be roughly classified in the following groups:

Demolition bombs
Fragmentation bombs
Chemical bombs
Incendiary bombs
Practice bombs

The purpose of demolition bombs is clearly indicated by the name itself; they are designed to demolish and destroy enemy objectives by detonation of their high explosive content.

These bombs can be equipped with intricate mechanical devices which control detonation, thereby providing safety elements for the crew and the airplane and controlling the explosion of live bombs. Bombs can be made to explode instantaneously or delayed.

The atomic bomb is the latest developed bomb used for demolition purposes. Another bomb that is being developed is a 42,000-pound bomb.

Fragmentation Bombs

Unlike demolition bombs, which depend upon both the blast and the spread of bomb fragments for effect, fragmentation bombs require only that sufficient fragments are thrown outward at high velocities. These bombs are used mainly against personnel. Results are often dreadful, due to the proper combination of explosive content and metal parts of the bomb case.

The first fragmentation bombs were made from rejected 3-inch artillery shells, weighing seventeen pounds.

Many of the fragmentation bombs were dropped by parachute. This was done to protect the low flying aircraft from fragments of the exploding bomb.

Chemical Bombs

Chemical bombs have several purposes, some of which may be combined at times to obtain the desired effects.

Chemical bombs may be used for casualty effects, screening, and denying territory to the enemy.

Incendiary Bombs

The incendiary, next to the high explosive, is the most dangerous for destruction of property.

Magnesium and thermite are now the most common substances encountered in incendiary bombs. Petroleum and pitch were used to start fires at docks and water front areas. They were effective because petroleum's greatest incendiary effect is upward.

Practice Bombs

Bombs usually employed for practice purposes are obsolete types, or else special practice types manufactured in a much cheaper manner than is possible for standard service bombs. A specially manufactured type weighs one hundred pounds. This bomb has a five-pound black-powder, spotting charge, with the remainder of the bomb being filled with sand.

At the start of bombing, the bombardiers carried their bombs in a basket in the cockpit and tossed them overside by guesswork aiming. By the end of the first World War, simple bomb sights and automatic release systems were designed.

3. AIRCRAFT MACHINE GUNS

The cal. .50, Browning machine gun, M2, has very appropriately been referred to as the basic Air Force weapon. Since the Air Forces adopted this gun, they have "babied" it along, always demanding more in performance. Consequently, it has assumed the status of "standard" in fire power equipment. However, only through a long history of development has this gun attained this coveted position. Today, gunsmiths are still at work seeking new improvements.

The first machine gun was of Belgian ancestry and was developed as far back as the year 1851. The French at once obtained the piece, named it the "Meteailleuse," and placed it in service. A picture of this ancient model resembles a modern "Rube Goldberg" in design. The breechlock contained thirty-seven chambers which corresponded to barrels. The breechlock was set in place with its chambers loaded and locked into position. By turning a crank, the firing mechanism of the lock tripped, thus firing the cartridges. A rate of fire was quite unique, being solely dependent upon how fast the operator revolved the crank. Three hundred and seventy shots per minute could be obtained with a highly trained crew of men.

Gatling

The first practical machine gun was the invention of an American, Dr. Richard Gatling. His early model appeared in 1862 and it was not until 1912 that another type of weapon superseded his model. This early American gun had the same multiple barrel set-up as that of the first French variety. However, unlike the latter gun, these barrels were not stationary but revolved, and each barrel had its own firing mechanism. As the barrels were turned by an operator, they revolved past a hopper on the topside of the gun, with their breech open, thus allowing a cartridge to be chambered. The breech was then automatically closed, the cartridge fired and as the barrel continued to rotate, the breech was opened and the expended case thrown out of the breech. The barrels then were ready for the next round. As can well be imagined, people were skeptical of this Civil War invention. So much so, in fact, that Dr. Gatling was forced to lure his own gunners, train them for his gun and then send the piece with its operators into battle with the Union Army. Only in this manner could he prove the worth of his invention.

Maxim

The real "father" of the modern machine gun, as we know it today, was another American named Maxim. This inventor journeyed to England and while there became vitally interested in the further development of the machine gun. He set up a laboratory near London and soon produced the Maxim machine gun, which in time was to kill more men than any other weapon ever employed. This piece, for the first time, delivered a high rate of fire power over a long period of action. It required no extra assistance in operation. Simply pressing the trigger and feeding it belt ammunition were the only manual labor steps necessary for its functioning. The gun itself utilized a single barrel with a water-cooled jacket which had a stream condenser attached to it, so that the gun might be fired over a long interval without mishap. Another feature of the piece was the utilization of the recoil of the explosion to operate the gun and to introduce belt feed.

Browning

The next prominent figure to enter the scene in the development of the cal. .50 machine gun is John M. Browning. It is with him that we usually associate the modern gun. He took advantage of chamber pressure and let off part of the gases by drilling a hole in the barrel near the muzzle. Cooling the piece was effected by a water jacket around the barrel. The Browning gun saw wide, effective service in World War I with the Air Corps. As might be expected in aerial operations, a barrel jacket with water-cooling was not necessary.

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The firing bursts were short and the rush of air over the barrel was sufficient to prevent over-heating. The foremost machine gun of today is the famed American cal. .50 Colt-Browning. Strangely enough, this gun that proved itself beyond doubt in warfare against both the Germans and Japanese, was developed by the Germans during World War I. The present type fires a spitzer-type projectile, weighing from 753 to 800 grains, the heavier bullet usually being employed in air combat. This bullet leaves the muzzle at the rate of 2500 feet per second, and has a striking force of 10,765 pounds. The rate of fire is between 750 and 850 rounds per minute. The gun is cooled by a perforated jacket, which supports the barrel, thus increasing the accuracy of the piece. So much for the gun itself. A more thorough and comprehensive study of the gun will be made in this course.

Browning's name looms large in the history of weapons. He was a natural born gunsmith and at the age of thirteen designed his first weapon, a wooden model. Browning invented the majority of Winchester pieces, both rifles and shotguns, up to the time of his separation from that firm. He likewise developed the majority of the Remington line and all of the automatic pistols manufactured by Colt, yet his name was never connected in their production with the exception of military weapons. Browning's pieces have also been manufactured in practically every country of Europe. During World War I, Browning's machine gun was adopted over the Maxim and Vickers models because it was more reliable in performance, cost less to manufacture, and could be produced more rapidly. Other features of his guns are their simplicity of design and positive performance. The Army .45 automatic pistol was first produced in 1905. At first it failed to appeal to the Army Ordnance Board because it desired a more complicated specimen. Accordingly, Browning redesigned the piece to meet their ideas. No automatic gun ever invented will stand the abuse of the famous "Model 1911, U. S. Army." The first machine gun developed by Browning came into view in 1890 under the name of Colt. It was immediately accepted by both the Army and the Navy. The same gun was used in the Spanish War and in China during the Boxer

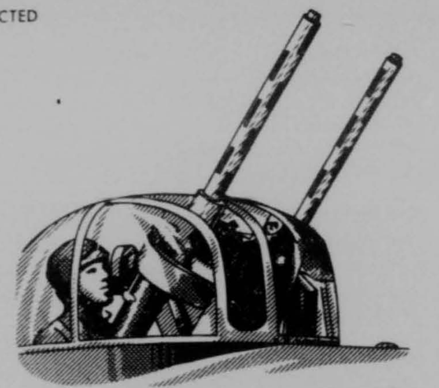

Figure 1—2. Topside. Twin Fifty-Caliber Colt-Browning Guns in a Power Turret on a B-25.

Rebellion. It was not until after the first World War that the present cal. .50 machine gun was brought on the market.

4. AIRCRAFT CANNONS

Machine guns are fast being replaced with aircraft cannons. Aircraft cannons are those in the range of 20 to 40-mm. The small bore cannon as employed by ground military forces are quite different from aircraft cannon. Years ago, before special cannon were developed for air combat, ground guns were merely adapted to airplane mountings without any attempt to redesign either the guns or the ammunition for the special requirements of aerial combat. The conditions which aircraft cannon had to meet were:

An exceptionally high firing rate for short periods of time.

A low weight of gun and ammunition.

The least possible recoil of the cannon.

A reduction of the size and primarily the length of the gun to facilitate mounting and manipulation while firing.

Fortunately, the very difference in the desired results in air and ground combat enabled gun designers and manufacturers to meet these requirements.

Out of these designs emerged the American 20-mm cannon. The 20-mm, 2,850 ft. per second automatic gun is a combination blowback and gas-operated aircraft weapon. The gun is air-cooled and has a cyclic rate of fire of 600

to 700 rounds per minute. It is designed for mounting as a fixed gun in the wing or fuselage of an airplane.

As early as 1933 the American Armament Corporation started developing a 37-mm fully-automatic cannon, specifically designed to be mounted on aircraft.

One model of this weapon may be mounted in the nose of the plane or in a gun turret in the body of the fuselage.

The B-25 and the B-26 have 75-mm cannons mounted in the noses of the fuselage.

The effectiveness of cannons is gradually being replaced by the use of rockets. The 4.5 rocket is equivalent to the 105-mm cannon in its destructive force.

5. THE ROCKET

A rocket is a missile propelled at high speed, by the rearward expulsion of gases generated by the combustion of an internally-carried fuel. It works in obedience to a natural law first recognized in the late seventeenth century by Sir Isaac Newton who propounded it, as the third of his laws of motion: for every action, there is an equal and opposite reaction. This will be discussed briefly here, but in more detail later in the course. The action of the gases from the burning fuel, in pushing rearward out of the rocket, is matched by an equally forceful reaction which pushes the rocket in a forward direction opposite to that of the flow of the gases. It is this reaction force which causes a rocket to fly through the air. It is not the push of the escaping gases against the atmosphere. A rocket can operate in a vacuum. In fact, the thinner the air the faster it flies, because there is less atmospheric resistance.

History

The rocket principle has been successfully incorporated in a number of mechanisms. The best known of these is fireworks. The rocket was first employed as a military weapon by warriors of Mysore, India, in fighting the British at Seringapatam in 1792. It has long been used as an instrument for signaling and as a life-saving device to carry lines from shore to stricken ships. It has found practical, scientific use in meteorological studies in carrying weather instruments to the highest altitudes. In the years between World War I and World War II extensive experimentation was carried on with rockets in Italy, Germany, and the United States, principally by experimenters banded together into rocket societies.

World War II

The rocket was introduced as a military weapon in World War II. Every major participant used it. Each nation developed this weapon in answer to its tactical and combat needs. The Russians pioneered in the firing of antitank rockets from planes, and in the use of massed banks of rockets for preassault barrages. The British used them for defense against attack from the air at a time when there were only five hundred antiaircraft guns in the United Kingdom. With their Luftwaffe driven from the skies, the Germans employed the long range V-2 weapon to attack England's cities. The Japanese unsuccessfully attempted to use rocket artillery to defend their island outposts. The United States, too, developed and introduced a great variety of rocket weapons. By the time the war ended, American soldiers, sailors, and marines had fired millions of rockets at the enemy. For this weapon, our armed forces could thank the team work of American science, industry, and the military at home. When the Japanese attack on Pearl Harbor catapulted the United States into the war, our Army and Navy had not a single rocket in service use and plans for their use were limited. By V-J Day, the Army was procuring rockets at a cost of $150,000,000 a year. The Navy had 1,200 war plants turning them out at a cost of $100,000,000 a month.

One of the most spectacular rocket weapons of the war was the German V-2. Allied technical intelligence provided information about the V-2 more than a year before it finally hurled out of the stratosphere to strike London. Our only countermeasure was to attack the launching sites with every means at our command. The Germans had been working on such a rocket since 1935. We had not. To start in 1943 to develop a similar American weapon would have required several years of intensive research on the part of our scientists in order

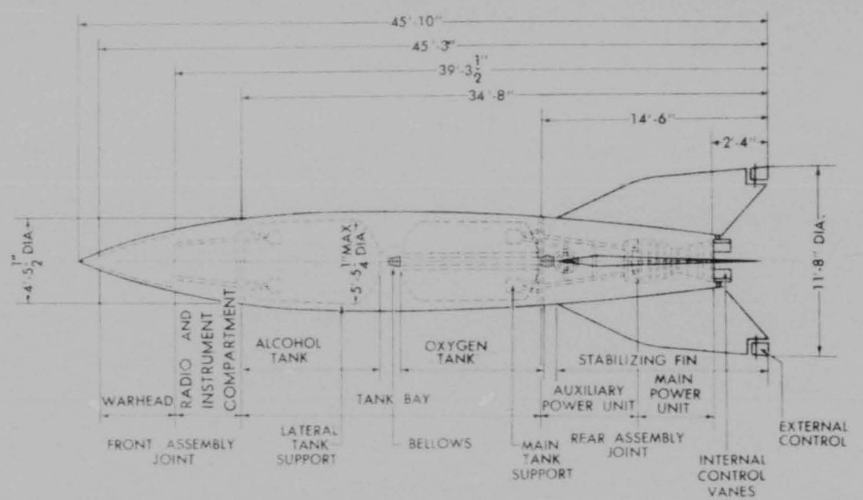

Figure 1—3. V-2 Bomb.

to provide the fundamental design data which German workers had accumulated over many years. The tactical importance of such a weapon to the Allies was not great enough to warrant the diversion of scientific manpower already thinly spread over a vast military research program which included the development of the atomic bomb. The American rocket workers, both military and civilian, had no store of basic data such as an adequate program of peacetime preparedness would have given them. The task of providing our fighting forces with rocket weapons would have been even more difficult and time-consuming if the British had not done experimental work with rockets before the war, and shared with us their knowledge and experience. As it was, the job was difficult. Every new project and improvement required an initial phase for the development of fundamental facts which a more complete program of peacetime military research would have developed in advance.

Their accomplishment is a tribute to the determination of the Army and Navy, to the imagination of American scientists, and to the productivity of American industry. Starting under a great handicap, they were able to produce the rockets which hunted down enemy submarines in the Atlantic and Pacific; the bazooka, first turned loose against the enemy in North Africa; the aircraft rockets which spearheaded the Normandy breakthrough in July 1944; and the barrage rockets which laid down a deadly fire ahead of our forces invading North Africa, Sicily, Italy, Normandy, and southern France.

6. GUN SIGHT AIMING POINT CAMERA

The present gun camera is essentially a small motor-driven, magazine-loading 16-mm motion picture camera, designed to be mounted near the sighting station of both fixed and flexible guns. In some cases it is mounted directly behind the gun sight to photograph the sight reticle as well as the target which is being fired upon. The use of gun cameras for the training of pilots in aerial gunnery and combat procedure dates back to World War I. It is believed that the first gun cameras were employed by the British and French sometime during 1915 or 1916. These cameras, though cumbersome and difficult to operate, proved their worth by more accurate and effective gunnery. Eastman Kodak Company produced the first American gun camera in 1918. Resembling a more advanced British gun camera, it simulated a cal. .30 machine

gun. It was powered by a spring-driven motor, wound before each mission, and used 35-mm film. A stop watch was incorporated. A picture of the watch was taken at the end of each burst fired, to eliminate disputes between the engaging pilots over who was accountable for the first vital "shot" which may have brought down his adversary's plane.

About 1938, these cameras were improved. They incorporated operation by electric motors, and with the improvements made in photographic lenses and film emulsions the 16-mm film replaced the 35-mm film with little if any change in the clarity of the picture.

Next came the magazine form of loading the cameras. The gun camera no longer took the shape of a machine gun as it was now operated by remote control and became a streamlined, cylindrical shape. This camera was the forerunner of the gun-sight aiming-point camera, an American invention, developed after a comprehensive study by Wright Field technicians. They sought to produce a new highly efficient piece of equipment better suited to the needs of aerial gunnery instructors. This gun-sight aiming-point camera will be discussed in greater detail in a chapter later in this course.

SECTION III—AMMUNITION

1. GENERAL

Fire power is measured in terms of amount of ammunition; that is, weight of ammunition that can be shot from a single gun or from all the guns of an airplane within a specified period of time.

This fire power must be delivered in a vital spot of the enemy aircraft if it is to be effective.

During World War I the stepped-up machine guns fired only about ten shots per second. To augment this lack of fire power, specialized ammunition quickly made its appearance. Accuracy was of prime importance because of this limited fire power. The ring sight was used, then the Aldis sight. Even with these aids the average pilot found it difficult to place every shot in a vital spot. Because of this, tracer ammunition was developed.

2. TRACER AMMUNITION

By observing the smoke trails and pinpoints of light, it is possible to ascertain the course of the gun's fire. Obviously useful, this ammunition is not without serious drawbacks. There is an optical illusion created at certain angles by the flame and the fire appears to be on the target when it is not.

In air fighting, the tracer has proved somewhat effective as an incendiary, particularly when gasoline tanks have been ruptured and free gasoline and fumes are present. The heat of the flame is sufficient to ignite the gasoline. However, against such targets as observation balloons widely used in World War I, the tracer proved a disappointment. The bullet would readily penetrate the envelope of the balloon but even sustained tracer fire bursts were not sufficient to ignite the escaping gas with any degree of certainty. As a result, another specialized type of ammunition made its appearance. This was the incendiary.

Incendiary ammunition of this type proved most effective against the raiding Zeppelins. Warneford, a British pilot flying an Avro, destroyed a Zeppelin over London the first time that this bullet was used against the raiders. It became certain death for the Zeppelins to be caught within range of these incendiaries. However, the use of this ammunition was restricted. Effective as it would have been against aircraft where the gasoline tanks were hit, it was not permitted to be used. Due to its "mushrooming" effect, it was classed as a "dumdum" and so banned by international agreement. When used against observation balloons, the pilots were issued written orders for the attack and these orders were carried with them during the course of the offensive action. If they were shot down during the attack, these orders covered the use of the ammunition and the pilots were not

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subject to execution as they would have been otherwise.

3. ARMOR-PIERCING BULLETS

Although protective armor as we know it today was not generally used during World War I, the value of armor-piercing bullets was early recognized. Hits with service ammunition on engines were not always effective. The bullets were, more times than not, deflected and slight damage resulted.

Due to the fact that this ammunition was of standard caliber, like all of the other specialized types, the size of the projectile was limited, and its effects were not sufficient to shatter an engine. It did, however, create damage which could cause engine failure. Against the heavy armor of tanks, this bullet was not effective. It lacked energy for penetration and merely embedded itself in the armor. The search for augmented fire power even led to the development of an explosive bullet of standard caliber. These bullets were actually nothing other than miniature shells. As a destructive agent the explosive bullet was not a success.

SECTION IV—TURRETS

1. GENERAL

Almost a decade ago it was foreseen that power-driven gun turrets would replace the open rear cockpit and open gun positions on large types of planes. The urgent necessity for providing an enclosed turret for the gunners was brought about by the increasing speed of aircraft. At two hundred miles per hour and more it became virtually impossible for the gunner to swing a twin-gun mount around. Increased number of guns per turret and larger weapons definitely forced the development of the power-driven, enclosed gun position. Among the early considerations for these turrets was the type of motive power that had to be accurate as well as sensitive, require little effort to operate, possess reserve power, and be comparatively light in weight. It had to be capable of smooth and instantaneously-variable speed from one direction of rotation to full speed in the other direction. In addition to rotation of the turret, controls had to be provided which would adjust the turret or gun mount in a vertical direction simultaneously with and also independent of horizontal motion.

Early Experience with Powered Turrets

The British were among the first to develop turrets successfully. The turret was mechanically controlled. But as hydraulic equipment came into being it was adapted to turrets. Then the turrets became fully electrical in their operation. These turrets were called local-control turrets because the gunner sat in the turret and moved with it.

Development of Remote-Control Turrets

Later came the development of remote-control turrets. These permit the best sighting positions on the airplane for the gunner, the best firing positions for the guns, and the most adequately protected position for the control mechanism.

A turret was even designed that was to be stabilized in azimuth and elevation. Then the pitch and roll of the aircraft would not affect the position of the turret.

SECTION V—GUN SIGHTS

1. GENERAL

The efficiency of fighter aircraft has been doubled as a result of the introduction of the compensating and computing gun sights. These sights take the element of guess out of aerial gunnery. The sights automatically figure the "fall" of the bullet because of gravity, the ballistic deflection caused by wind, and the amount of lead required to hit a target. Shooting from a fast-moving platform at a faster moving target makes the problem even more involved. These factors are also affected by air speed, density, and altitude. The sight compensates for these factors.

So far as the gunner is concerned, when using the automatic device, he seems to aim directly at the target. The sight, however, points the gun automatically and continuously at the spot where the target will be by the time the bullets arrive. The gunner makes no mental calculations.

Gun Sights with Radar

Today, gun and bomb sights work on radar. With this principle the gunner does not have to see his target visually. The invisible waves will paint a picture of the target on a screen before him. From the screen, he can determine when to fire the guns or drop the bombs.

SECTION VI—THE DEVELOPMENT OF AERIAL CHEMICAL WARFARE

1. INTRODUCTION

While customarily considered a new weapon of battle, chemical warfare is in reality one of the oldest of the arts of war. It should be understood that the term "chemical warfare," as applied to the ancients, deals almost exclusively with the use of incendiaries. Fumes and smokes were used, as such, at a much later date. No one knows when the first incendiary was used, or who first realized the tremendous power of fire as an agent of destruction. It appears reasonable to assume that the use of incendiaries commenced long before the record of man's activities was painted or carved on the walls of caves. It is entirely possible that the accidental igniting of dry grass demonstrated to the primitive people the great power of flame as an agent for driving game from cover into the open. This idea, first put into practice in the hunt, later may have been turned to advantage in the forcing of an enemy from his place of concealment or protection.

Fire Arrows

Herodotus records the use of fire arrows by Persian archers at the taking of Athens during the invasion of Xerxes in the year 480 B.C. This is the first written record of the use of this weapon on Greek soil. There are, however, Biblical references which trace the fire arrow back to the eighth century, B.C. That the fire arrow proved to be a valuable weapon is evidenced by the fact that it was still in use in the year 1860 when it was employed by the Chinese against the French.

Gas

Sulphur was used in war at an early date. This is borne out by the record of the siege of Plataea in the year 429 B.C. During this operation, the Spartans heaped fagots in the open space between the wall of the town and the inner fortification. These fagots were thrown from within the Spartan lines and after a great heap had been so deposited, balls of blazing pitch and sulphur were tossed onto

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the heap to ignite it. In his "History of the Peloponnesian War" the Greek writer Thucydides states that this operation would have been entirely successful if a sudden rainstorm had not extinguished the flames. Five years later the fortification of Delium was attacked in a somewhat similar manner. In this instance, an iron cauldron filled with glowing coals, pitch, and sulphur, was brought near to a portion of the wall that was of timber construction. A ship's spar was hollowed out to resemble a tube, and lined with iron. This spar was connected to the cauldron by means of an iron snout that extended from within the spar downward to the cauldron. A bellows was applied to the other open end and air forced into the cauldron, causing a great burst of flame and very intense heat. Thucydides relates that this machine was so successful in its operation that the wall of the fortress was consumed and the defenders driven away in panic. While pitch and sulphur were used in both of the foregoing operations, the accounts would seem to indicate their use as an incendiary only. They were not credited with any value as producers of stupefying and asphyxiating fumes. It is difficult to believe, however, that by the time of the siege of Delium the Spartans had not begun to realize in some manner the overpowering effects produced by the fumes of burning sulphur. It is entirely possible that this material was used in this latter instance as an asphyxiating agent as well as for its incendiary effect. Thus, we have examples of the early history of both incendiaries and asphyxiating agents as used in chemical warfare.

2. FUNDAMENTAL REASONS FOR CHEMICAL WARFARE

The instances of the early use or suggested uses for chemical agents are of little importance insofar as their effect on the science of warfare is concerned. They serve to show, however, that the introduction of chemical warfare in war was not accidental, but was due to fundamental causes; that its development parallels that of other forms of warfare. As the fortifications and natural defenses of the ancients became more nearly perfect in their protection against the existing weapons and means of defense, a situation of deadlock was reached; resourceful commanders searched for new weapons and means to overcome the protection. In this search, they naturally turned to the developments of peaceful pursuit. When firearms were introduced about the beginning of the fifteenth century, the protection afforded by fortifications decreased and warfare again took to the open. With this increasing mobility on the part of combatants, suggestions for the use of chemical agents declined until the increasing power of offensive weapons drove the defense to cover. With the underground system of defense of World War I, protection was obtained, but an impasse was reached. The offense could not go forward. Some practical means had to be found again to overcome the protection. The natural, logical thing was to find some weapon to reach down into the deep trenches and dugouts. Gases offered the ideal solution, and chemical warfare in its present sense was begun; for the first time in its history, all conditions necessary for its successful use were present. These conditions were: the availability of large sources of raw materials, the existence of a highly developed and efficient chemical industry with its training, and battle conditions resulting from a state of balance between the offensive and defense. Chemical warfare thus became effective.

Chemical Warfare Service

The Chemical Warfare Service, as created on June 28, 1918, by the President was an emergency organization to remain in force not longer than six months after the termination of the war emergency. In 1919, its continuance until June 30, 1942, was authorized. After consideration of all available information and data, and due, largely, to the recommendations of General Pershing and other leaders who had experience in France, Congress made the service a permanent component of the Army by the National Defense Act, as amended June 4, 1920. By this act the service is charged with the investigation and development of smoke and incendiary materials, toxic gases, and gas defense appliances; the research, design and experimentation connected with chemical warfare and its materials; the procurement and supply to the Army of all smoke and incendiary material, all toxic gases and all gas defense appliances; the operation of shell filling plants and proving grounds; the organization, equipment, training, and operation of special gas troops; the operation of necessary schools of instruction; the supervision of the training of the Army in chemical warfare, both offensive and defensive; and such other duties as the President may prescribe.

3. AERIAL CHEMICAL WARFARE

There is no record of chemical attacks from the air during World War I. Today, however, it has been demonstrated that the airplane provides the most effective method of disseminating the various types of chemicals by spray or by bombs. Early in 1936, the Italians used mustard gas in aerial attack upon the unprotected and untrained Abyssinian Army. This is the first record of aerial chemical spray being used in warfare. Attack aviation is particularly suited to the dissemination of chemical sprays and the laying of smoke screens for concealment. Where in World War I it was possible to subject only front line areas to chemical attack, in World War II any area over which strategy aircraft could fly was subject to chemical attack. Early in the war incendiaries were used by both the enemy and the allies. Germany dropped incendiary bombs on London; we in turn used incendiary bombs against chemical plants, refineries, oil fields, and similar strategic targets far behind enemy lines. Late in the war with the introduction of napalm, a gelatinized petroleum substance which was highly inflammable, attacks were made on smaller targets, such as moving columns of vehicles and gun positions. The methods of spraying and the equipment used in chemical warfare will be described later in the course.

SECTION VII—FUTURE TRENDS OF ARMAMENT

1. GENERAL

The immediate future in air warfare will show radical advances in the actual weapons, as well as changes in quantities of aircraft used in bombing attacks, in numbers of fighter escorts, and in new tactics and techniques of mass air raids and battle maneuvers.

The machine guns of old and those still in use today will be largely, if not wholly, supplanted with shell-firing cannon of various calibers, with rocket guns supplementing or even replacing them in some instances. The lower calibers of shell-firing cannon will be employed for turrets and multigun wing installations, and the higher calibers for the huge flying boats and flying fortresses, and as engine-mounted cannon firing through a hollow-propeller hub.

The fixed-wing cannon, together with the flexibly-mounted ones in turret-gun positions, will gradually become more effective as airplane speeds increase, and as more room is made available in which to mount the guns with greater ammunition loads.

2. ARMOR PLATE ON MILITARY AIRCRAFT

It is probable that improved armor-piercing shells will be employed in the future. They will have greater penetration to offset the increased use of armor plate on all types of military aircraft. Indeed, a seesaw struggle has been on, and may continue in the future, between the ordnance designers on the one hand and the steel men on the other. The latter are manufacturing better armor plate against which only guns of high caliber can be effective—calibers that already have run as high as 75-mm. Although three-inch shells, when fired from cannon mounted on airplanes, have been designed to have a shorter range and lower muzzle velocity than similar bore ground weapons, they nevertheless have a tremendous explosive effect once armor plate or other parts of the airplane are struck. Additional armor plate cannot be placed on airplanes indiscriminately, however.

Besides concentrating the armor protection around the gun positions, it may be possible to have this armor adjustable or rotatable. Since fire normally will come from the direction in which the defending airplane's own guns are pointed, armor plate that protects only in this direction will be quite sufficient. In some cases, small pieces of armor plate have been attached directly to the single, or twin, machine-gun mount so as to protect the gunner's head and chest. These pieces weigh but little and protect fully where most needed.

Future Armor Plating for Aircraft

Undoubtedly, the fighting airplane of the future will be a clever design, one which may employ a more or less universal type of construction. It may have interchangeable armament sections in order that a number of machine guns, or cannons, or bombs can be carried; it also may have replaceable armor plating so that for various combat missions the airplane can be either with or without the protective plating.

To eliminate the principal disadvantage of armor plating, that of added dead weight, the possibility exists that a system of droppable plates can be carried by aircraft. The purpose of this is readily obvious. While a bomber is carrying its load of bombs into enemy territory, and during the performance of its mission in locating the target and unloading the bombs, the armor protection would be available. Due to the bomb load, the speed of the bomber is somewhat reduced, as is its maneuverability. Once the bombs are released, however, the bomber is expected to return to its base with the greatest speed. Furthermore, armor plating may be so designed that it can be mounted on the outer surfaces of wings and fuselage, or over vulnerable inner parts of the fuselage. When released in a manner similar to bombs, flares, or droppable fuel tanks, a reduction of one thousand or more pounds may be effected and the bomber can return with the speed and maneuverability of its empty rating. This idea, carried through to development, appears to offer the answer to several problems at the same time: protection during operations over enemy ground, and the best speed and altitude performance of which the bomber is capable without its combined bomb and armor plating load after completing its mission.

3. AIRCRAFT ARMAMENT IMPROVEMENTS

Improvements in aircraft design, reflected in recent innovations in airplane structures, engines, and accessories, are being accompanied by numerous advances. These advances are in armament mountings, simpler and more efficient gun turrets, wings designed around a multiplicity of cannon, and a host of other changes destined to make an air force a more effective striking weapon against enemy air, sea, and land power.

New airplane types and new bombs will see future bombing deviate from practices now employed. Extremely low-level attacks may take place under more favorable conditions for the bombers; substratosphere bombing and fighting also is in the offing.

Dive bombing will be aided by the rocket bombs, already in limited use. After being released in a dive toward its target, the bomb is kept from following its natural trajectory by a propellent which sends it along a straighter path, resulting in greater accuracy. Incidentally, the airplane need not come down to such a low level in the dive.

The substratosphere will be the operational sphere of the huge military transports and bombers to come. Crossing continents and oceans, these battleships of the air will thereby keep out of sight and range of all ground defenses. They will be above all adverse weather conditions, and in general fly on their missions with the timing which only these conditions will permit. There will be air fleets moving in the upper air lanes, fleets of all the belligerents, if the war is to be of long duration.

The only defense against these armadas will be the fighters who can stay up at extremely high altitudes long enough for patrol duty and still be able to outfly and outfight the inherently-slower and less-maneuverable bombers and transports.

Substratosphere fighting airplanes must be detected long before they reach vulnerable objectives, and when so detected, must be destroyed or diverted from their missions. It is obvious that such a procedure will require not only great quantities of airplanes, but

hard-hitting, positive-acting weapons on them.

On the one hand, there is the huge bomber on which heavy defensive guns and armor plate must be increasingly incorporated, because of its importance both in capital value in cash and crew, and in its intangible but undeniable power of destroying enemy objectives. On the other hand, there are the interceptor fighters whose sole duty it is to intercept these bombers and knock them out of the air before they arrive at their targets. This also calls for weapons and methods of using them that will enable the fighter pilots to combat the huge bombers with confidence and on a more than equal basis.

Merely to increase the speed of airplanes is not enough. High speed is valuable for every military plane purpose. But when the specific moment comes, whether it is in level bombing, dive bombing, or attacking an enemy airplane with gunfire, the attacking airplane must either so lower its speed or reduce control of maneuverability so as to become vulnerable to the enemy, or continue at extreme high speed and lose the time and opportunity of careful aiming and prolonged firing. Despite the amazing rates of fire of which machine guns and cannon are capable, the actual number of bullets or shells which can possibly hit an airplane are few and far apart. The days of following an enemy airplane on his tail are gone. One burst of fire, usually a burst that is aimed ahead of the enemy airplane in some one direction, is practically all that can be expected in air battles between fighter planes. Despite a superiority in speed, fighters that attack large groups of heavily-armed bombers are also at a disadvantage because they have sufficient fire power massed against them to keep them out of range.

Whether offensive or defensive action is considered, the problems are identical, and the answer is similar. More and heavier guns will be built into airplanes, more ammunition per gun will be carried, and more armor plate installed. While acknowledging the extreme difficulties involved, it is expected that there will be developed new sighting apparatus that will positively correct for errors, and also new types of ammunition that will overcome the inherent faults of present shells with their deviations. For the large aircraft, timeable shells may be used, and thus add a new danger to fighter craft equipped with smaller weapons only.

Prophecies on Future Air Warfare

Contrary to the many fantastic prophecies that one may hear concerning future air warfare, it is not likely that in the next generation air staffs of belligerent nations will be sitting safely behind desks pressing buttons to actuate and control robot bombing fleets. However, there can be little doubt that automatic manipulation will play a more prominent role in any future war. To say that another war within the space of the next two or three decades would be totally destructive likewise seems a bit farfetched in the light of developments during World War II. Despite any assurance that total destruction may be avoided, air warfare has shown conclusively that the havoc which can be wrought demands the most earnest and serious efforts toward maintaining an enduring peace.

4. DUPLEX PROJECTILES

In the weapons that comprise either aircraft or antiaircraft armament, including machine guns, small-caliber rapid-fire automatic cannon, as well as heavy antiaircraft artillery, the final word as far as results are concerned depends on the ammunition used. After all, it is the projectile itself that brings down the enemy airplane. True enough, the guns must be accurate, mountings secure and flexible, turret bases precise, but the projectile that whines through space on its way towards an enemy must have two primary characteristics: it must have accuracy; it must have high velocity.

Both rotational and transverse velocities of projectiles can be made to vary by adjustments in the gun itself. For example, it is possible to obtain higher spin by varying the length of barrel, or by making the barrel smaller than the ammunition and thereby forcing the ammunition through it. Adjustments also can be made by adding more propellent material in the cartridge or shell case. This gives added power and range.

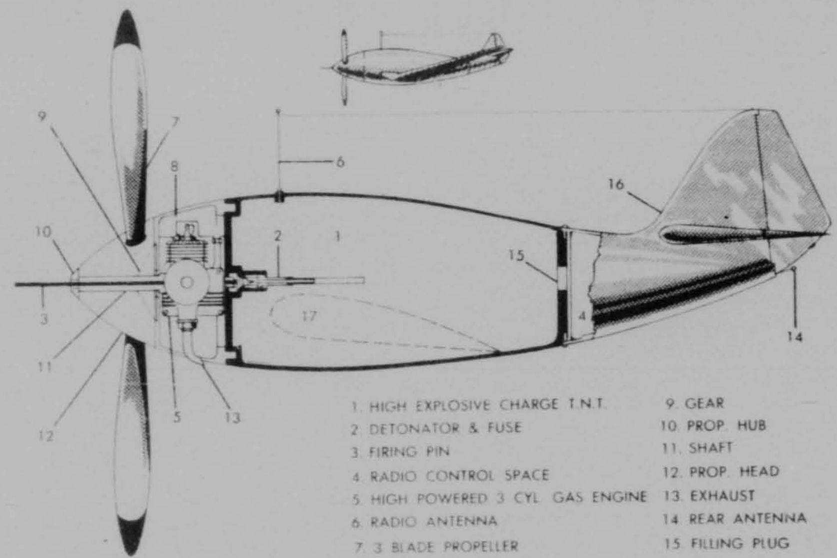

Figure 1–4. Radio-Controlled Robot Plane.

Projectiles in Flight

Before going into a description of an unusual type of projectile that combines accuracy with exceptionally high velocity and long range, it might be well to examine briefly the conditions that exist for projectiles in flight.

It is known that machine gun bullets have an initial velocity of about 2,700 feet per second (compared with the speed of sound, 1,100 feet per second). Yet it is amazing how greatly this velocity is progressively reduced by the resistance of the atmosphere. This resistance is affected not only by the shape of the entering form of the projectile, but also by the form of the trailing mass as it sets up turbulence behind the bullet.

The compressibility of air at velocities above that of sound has brought about the development of contours commonly known as "streamlining"; in other words, an extremely-pointed entering shape to overcome the impact resistance offered by the atmosphere. However, as the initial velocity is reduced and approaches the speed of sound, the turbulent air currents at the rear of the projectile become of increasing concern. Experiments are being conducted in an effort to solve the problems of turbulent air currents.

5. PRECISION ROBOT AIRPLANES

One of the most startling possibilities in future air warfare appears to be the development of radio-controlled robot airplanes that can accompany heavy, long-range bombers to their distant objectives. Large bombers, despite their numerous gun stations and heavy armament, are always vulnerable to numerically superior and faster enemy fighter aircraft because they are of themselves slower and more cumbersome. Fighter aircraft cannot accompany them on distant missions because the normal fuel capacity of fighters is limited.

Radio-controlled Planes

As part of the bomb load, these huge flying fortresses could each carry one or two tiny radio-controlled planes. These miniature planes would have folding wings so that they could be stowed away in the fuselage of the larger mother ship, the two airplanes being staggered to fit with the least possible interference into the faired-away interior. They would have small and inexpensive engines fed from fuel tanks of rather small capacity, since their radius and duration of action would be intentionally limited. They would carry a gyro pilot, controlled by a robot mechanism activated by radio impulses transmitted from the mother plane. They also would carry several bombs and smoke-screen gas tanks. The bombs could be detonated by radio.

In no branch of aerial warfare has there been any weapon exhibiting the versatile possibilities of these radio robot planes. They could be hung upon special hooks within the fuselage and the crew could lower them through the fuselage doors, open and lock the wings, start the engine, check the radio control, and release them for free but controlled flight within the visual range of the radio control operators. Carrying their timetable bomb load, they could be directed into formations of enemy aircraft to create havoc among them; they could be used to divert and prevent attacks upon the bombers themselves. They could be sent into enemy ground objectives with more accuracy and with less danger to the bombers than any precision-aimed, free bomb drops. They could precede or surround the bombers they protect, sometimes emitting smoke screens to confuse enemy aircraft.

Since they could not be retrieved, and since they should always destroy themselves with their deadly cargo, they may be constructed of nondurable materials. Being small and light, they could be produced in huge quantities at comparatively low cost. They would represent an enormous "suicide force," which would not risk a single life of the operating forces. While they could be adapted equally well to protect shipping when operated from surface vessels, their greatest all-round use would be as bomber-based flying bombs.

Radio-controlled Bombs

Unlike the robot planes and bombs previously described in the chapter on self-propelled ammunition, this particular radio-controlled bomb would have several unique features differentiating it sharply from long-range robot planes controlled by set mechanisms. The latter must have sufficient instruments to detect, correct, and compensate for variations in air density, winds, and course changes caused by exploding antiaircraft shells. Being controlled within the limits of visual range from mother aircraft (these limits may extend up to a hundred miles under good weather conditions if observed through high-powered glasses and if equipped with smoke-trail apparatus), the flying bomb is not a robot in the sense of those that are launched with pre-set controls. If anything, it becomes more of a precision bomb than those which are dropped in free flight and over which no further control can be exercised.

Essentially, this radio-controlled bomb could be made in three sections which could be nested into each other for final assembly. The forward section, or nose, could contain the small compression-ignition engine, together with fuel tanks and propeller. Due to their short range action, fuel tanks would be relatively small. The center section would be the actual bomb containing the explosive, which could be detonated either through the firing pin extending through the forward power section past the propeller spinner or by means of radio through a detonator operated from the rear section. The rear section would carry the radio receivers connected directly to tail-surface controls. Connecting rods, cables, and wires, therefore, would be direct and short. The wings would set into special recesses and hooks on the center section.

While controllable bombs of this type would cost more than free drop bombs of similar weight, they might, in all likelihood, reduce heavy bomber losses because the latter could remain well away from the target area in any direction.

6. ULTRAHIGH-SPEED GUN

Endeavors to improve existing weapons,

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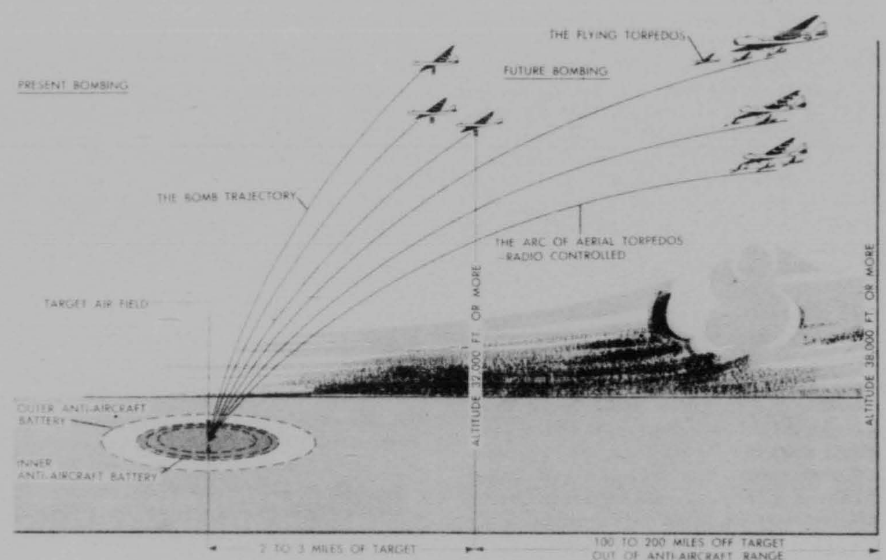

Figure 1—5. Present and Future Bombing by Radio-Controlled Aerial Torpedoes.

particularly from the standpoint of fire power, may lead to the time when even 20-mm cannon can be made to fire at a cyclic rate of several thousand rounds per minute. With the ultra high-speed gun regarded as a theoretical possibility, some predictions as to how the problems involved may be surmounted would seem to be in order.

The principal deterrents to actual construction and operation have been the difficulties in designing simplified feeding and firing mechanisms, and a gun barrel that would withstand the tremendous overheating and erosion from what would be tantamount to a continuous stream of steel through it. Such barrels, unless made from hitherto unknown metals, could last but a few minutes of total firing time and probably would have to be replaced after every flight.

It may be possible that high-speed cooling means can be evolved for these "stream" guns. Successful methods have been developed in which small-arms ammunition actually cleans the gun barrel during firing. Perhaps a system of changing or switching barrels in flight may be invented. Obviously, such schemes entail increased weight to the airplane due either to barrels or excessive amounts of ammunition.

Rocket Guns

The rocket appears to have the edge in future air armament. The high speed of the heaviest of bombers, combined with the amount of armor plate and other protective means they can apply to prevent damage from ordinary gunfire, point to the definite necessity of rocket guns and shells of naval-gun proportion being developed. Progress in this

direction is being made at this time. The primary disadvantage of rocket projectiles is their size. While deliberately made in large calibers for great explosive effect at the target, they also have to carry their own propellent material. A rocket equivalent to a 20-mm armor-piercing shell would be several times larger than the latter. This precludes a high-speed firing of such rockets since special feeding mechanisms would have to be designed. In conventional guns, as generally known, the force of recoil or the expansion of the propellent gases serves to operate the feeding of ammunition from belts or drums.

Conceivable Improvements in Automatic Guns and Ammunition

By the same token, it is conceivable that automatic guns and ammunition may be in for improvement by the adaptation of a principle used by the military a century ago. This will be illustrated in subsequent paragraphs outlining the author's conception of a possible aircraft or antiaircraft gun capable of being fed thousands of rounds of ammunition per minute.

From an airplane armament standpoint, the weight of cal. .50 bullets and small caliber cannon shells and the space required to carry them are still serious problems. One way of reducing the weight, and at the same time enabling several times the present amount of ammunition to be carried, would be to do away with the complete round by using the actual bullets or shells without the cartridge or shell cases. In effect, this would represent a return to the principle of separate-loading ammunition for small arms.

Gun chambers and feeding mechanisms for bullets alone could be less complicated mechanisms than at present required. No cartridge-case ejection mechanisms would be necessary. Firing rates conceivably might be stepped up to two thousand or three thousand rounds per minute cyclic rate. The propellent might be fed separately in special pellets, the container of which would be consumed within the firing chamber. Still more preferable would be a method of automatically feeding the propellent mixture through a flexible, armored pipe line directly into the chamber. The required amounts of propellent would be passed into the chamber behind the bullet or shell through a combined vacuum and pressure system used in conjunction with a mechanism that would effectually seal the chamber from the propellent feed line. The action of the gun itself, or possibly auxiliary pressure sources, could be made to clear a safety area behind the propellent cutoff after each bullet or shell had been fired. Possible, too, in such an arrangement would be a means of either manually or automatically controlling the amount of propellent while the gun is firing, which in turn would affect the firing rate, range, and gun barrel wear.

Firing could be done electrically. The problem then becomes one for the metallurgist and chemical engineer to consider. The tremendous heating of rifled gun barrels requires either a positive means of rapid and constant cooling, or a radical departure from conventional rifled barrel and ammunition design.

A striking solution to this problem is offered by a nonrotatable projectile which might be fired from conventional-type guns with smooth bores. Such a projectile was patented in 1930 by Peter Van Essen, of the Netherlands, and is covered in U.S. Patent No. 1,742-836. The patent is worth while studying as this projectile may have significant application in the future.

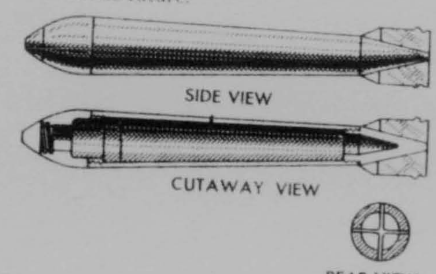

Figure 1—6. Van Essen Projectiles.

Van Essen's projectile is of such shape that the chamber pressure in the gun may be applied to a substantially large surface thereof, thus avoiding customary rearward thickening of the walls in a projectile of so-called normal design. Another object of the invention is to provide a projectile adapted to be fired effectively under wide variations in the angle of

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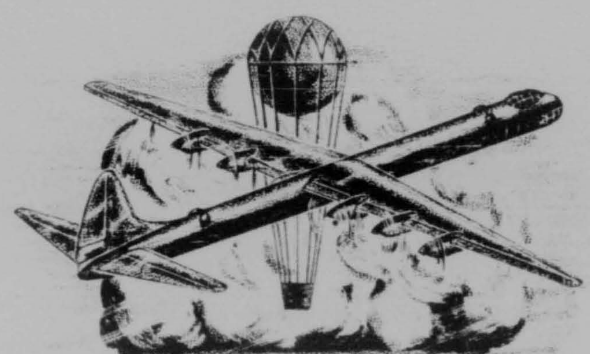
elevation, without relying on its rotation about its axis to retain its position along the trajectory.

Experience has shown that rotating projectiles fired at high elevations drift out of their normal position tangential to the trajectory. This deviation impairs the proper functioning of direct impact fuses, and also results in a deepened dispersion zone and loss of concentration on the objective. The use of wind vanes, as a means of correction, is effective only at the expense of the remaining energy of the projectile.

The conditions are still more difficult in the case of projectiles having no initial rotation, as, for example, those fired from smooth-bore guns. While admitting the virtues of having the center of gravity as far forward as possible, and the stabilizing influence of wind vanes and similar contrivances, a further disturbing factor is introduced. This is the influence of gas pressure immediately after the gas checking portion of the projectile has left the muzzle of the gun. This pressure may cause a deviation of the axis of the projectile from its proper trajectory; the deviation may be further aggravated by the fact that the projectile is not rotating.

This new method of construction provides a projectile substantially nonrotatable about its axis and having the known advantages of a forwardly-placed center of gravity and corrective wind vanes. However, by tapering the body of the projectile rearwardly and providing centering means at the rear of the tapered body, a gradual release of gas pressure is effected while guiding or centering the projectile until it has been substantially released. By these means it is possible to obtain accurate and effective firing even at high angles of elevation, and to reduce substantially the depth of dispersion usual in ammunition of this type. New devices are under constant study in order to maintain the highest standards of armament.



CHAPTER 2—TECHNICAL PUBLICATIONS

SECTION I—DEPARTMENT OF THE ARMY PUBLICATIONS

1. INTRODUCTION

Prior to the armed service unification in 1947, the USAF was a part of the Army. Up to this time all the publications dealing with policies, orders, instructions, and information issued by the Army were applicable to the Air Force. Now that the Air Force is a separate department it is issuing its own publications. However, many issued by the Army are still applicable to the Air Force.

Since this condition exists, it is necessary that every Air Force officer learn the different types of publications that are issued by both the Department of the Army and the Air Force.

Note: Not all the publications will be discussed in this section, but only those that are of importance to the armament officer. Also the publications that pertain to supply matters will be discussed in the section titled "Armament Supply."

One of the primary duties of an armament officer is the proper maintenance of armament equipment.

Efficient maintenance requires that operating and maintenance personnel have available and properly use the latest technical information and operating directives applicable to their work.

Complete maintenance information is available in existing publications, therefore, technical libraries will be established and should be used to the maximum extent.

In general, the information and instructions applicable to maintenance of the technical services will be contained in Department of the Army publications. Information for the Air Force equipment and supplies will be contained in the Department of the Air Force publications.

There are other publications which are general, tactical, or administrative in nature rather than technical. These publications will be published by both the Department of the Army and Air Force.

Rather than explain these publications as to technical, tactical, general, or administrative nature, this section will list the publications that are issued individually by the Department of the Army and the Department of the Air Force.

Only by constant use of these publications will it be possible to understand the information contained in each. Many of these publications are interrelated as some may supplement others.

2. ARMY REGULATIONS

Army Regulation 1-15 gives the general provisions of Army Regulations. The following quotes from AR 1-15 are included as an example: "Within their scope they have the force and effect of law to the Army and those whom they concern and are binding and conclusive." "Army Regulations are the primary administrative regulations for the government of the Military Establishment." Administrative regulations and closely related material appear also in other forms, some of which are as follows:

Circulars, Memorandums, and Letters. Administrative regulations of wide but temporary application appear in circulars. Regulations of more permanent nature are also frequently published in circulars pending their incorporation in AR's or changes to AR's. Regulations of limited application are published in memorandums and letters.

The "Index of Administrative Publications" is found in Special Regulation 310-20-5.

Reference tables and explanations of detailed procedures to aid compliance with administrative regulations are published in:

Field and Technical Manuals (FM and TM)

Field Manuals (FM) constitute the primary means of promulgating the basic doctrines of military training and operations. They contain training instructions relative to tactics and techniques (Figure 2-1).

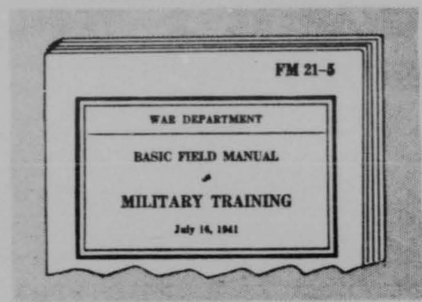


Figure 2—1. Military Training (FM 21-5).

Technical Manuals supplement Field Manuals, covering subjects the separate treatment of which is considered essential to a full accomplishment of the training prescribed in the Field Manuals. These manuals also describe materiel and contain instructions for the operation, care, and handling of equipment of the technical services. The instructions on any given item of equipment are published in manuals as follows:

Operator's Manual. For use of the arms and services. This covers only the operating instructions and such maintenance operations and procedures as are performed by the using organizations.

Service Maintenance Manual. This covers all the operations and procedures which are performed by field and base maintenance and includes the technical information necessary for disassembly, reassembly, and rebuilding of the item. Operator's Manuals and Maintenance Manuals are sometimes published under one cover as combined operation and maintenance manuals.

Technical Manuals are also guidebooks for instructors and specialists; they contain material for extension courses; reference books; administrative materials, supplementing Army Regulations; and similar specialized subject matter.

An example of a Technical Manual is illustrated below (Figure 2-2).

Field and Technical Manuals are numbered according to a single comprehensive system. Each manual carries a basic number (the first

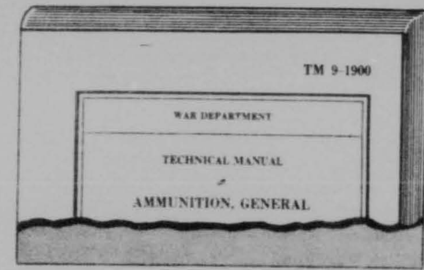


Figure 2—2. Ammunition, General (TM).

number) and a subnumber (the second number). The basic number identifies the subject matter to which the manual applies. The subnumber is a further means of identifying the publication within its particular class.

Basic Number. Examples of basic numbers that are allotted to subject matter follow:

1. Air
3. Chemical Warfare
9. Ordnance
23. Basic Weapons
38. Supply Procedure

Subnumbers up to 199 are assigned to Field Manuals; subnumbers 200 and higher are reserved for Technical Manuals. For example:

8-5 is a Field Manual in the Medical series, the basic number is 8 indicating Medical and the subnumber 5 showing that it is a Field Manual.

8-233 is a Technical Manual in the Medical series, the subnumber 233 indicating that it is a Technical Manual.

3. TECHNICAL BULLETINS

New instructions and information regarding maintenance operations and procedures may appear as Department of the Army technical bulletins prior to publications in a Technical Manual or change thereto and are subject to rescission when incorporated in new publications.

Technical bulletins will not contain material pertaining to tactical training or tactical operations.

Technical Manuals are numbered as explained below:

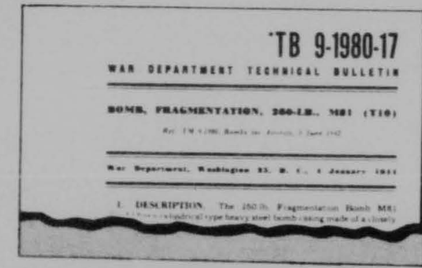


Figure 2—3. Bomb, Fragmentation, 260 lb. (Technical Bulletin).

Bulletins pertaining to Technical Manuals bear the number of the manual with an added serial number to differentiate one bulletin from another on the same subject. Example: TB 9-1980-17 indicates the seventeenth technical bulletin which affects TM 9-1980 (Figure 2-3).

Bulletins which do not pertain to a single Technical Manual bear the abbreviation of the originating service and are numbered consecutively. Example: TB CW 25 is the first Chemical Warfare technical bulletin not directly pertaining to a single technical manual (Figure 2-4).

4. TRAINING CIRCULAR (TC)

Training circulars are designed to promulgate—

New training doctrine.

Training doctrine, tactics, or technique, the immediate dissemination of which is essential.

Training policies or information of temporary nature or not relevant to the scope of existing manuals.

Training circulars are numbered in consecutive series for each calendar year.

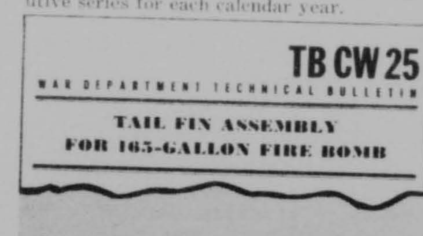


Figure 2—4. Tail Fin Assembly (TB CW).

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5. LUBRICATION ORDERS

Lubrication orders are illustrated, numbered, and dated cards or decalcomania labels which prescribe organizational lubrication instructions for mechanical equipment. They will be carried with, or attached to the equipment to which they pertain: instructions contained therein are mandatory.

6. MODIFICATION WORK ORDERS (MWO)

They provide authentic and uniform instructions for the alteration and modification of United States Army equipment.

For additional information on the explanation and scope of the Department of the Army publications see AR 310-20. DA Circular 41, 1949 makes the following changes:

Publication Indexes

The last edition of FM 21-6 to be published and distributed is dated 1 January 1949.

In the future the indexes of publications and blank forms now published in FM 21-6, AR 1-15, and AR 1-10 will be published in the following Special Regulations:

SR 310-20-3. Index of Field Manuals, Training Circulars, Firing Tables and Charts, Graphic Training Aids, Army Training Programs, JANAP's, Combined Communications Board Publications, Tables of Organization and Equipment, Tables of Allowances, and Tables of Basic Allowances.

SR 310-20-4. Index of Technical Manuals, Technical Bulletins, Supply Bulletins, Lubrication Orders, and Modification Work Orders.

SR 310-20-5. Index of Administrative Publications (Army Regulations, Joint Army-Air Force Adjustment Regulations, General Orders, Bulletins, Circulars, Commercial Traffic Bulletins, Joint Procurement Circulars, and Department of the Army Pamphlets.

SR 310-20-6. Index of Blank Forms and PRT's.

SECTION II—DEPARTMENT OF THE AIR FORCE PUBLICATIONS

1. INTRODUCTION

Department of the Air Force official publications will provide, insofar as practicable, all the information needed by individuals and elements of the Air Force in the performance of official duties. Air Force Regulation 5-5, titled "Department of the Air Force Publications," prescribes the types of publications issued by the Air Force. Distribution formula for Department of the Air Force publications is prescribed in AFR 5-4.

Following is a list of the publications an armament officer will be concerned with in the performance of his duties.

Note: Publications issued by the Air Force that concern supply primarily will be discussed in this manual under the title "Armament Supply."

2. AIR FORCE REGULATIONS (AFR)

Air Force regulations are the primary administrative regulations for the government of the Air Force and contain directives, policies, and administrative instructions of permanent and wide application. They are binding and conclusive upon the Air Force and those whom they concern.

3. AIR FORCE LETTERS (AFL)

They contain matter that is directive in nature, general in application, but temporary in duration.

4. AIR FORCE MANUALS (AFM)

Air Force regulations requiring voluminous detail may be augmented by Air Force Manuals.

*AFR 5-2
1-4

AIR FORCE REGULATION)
NO. 5-2)

DEPARTMENT OF THE AIR FORCE
WASHINGTON, 6 August 1948

PUBLICATIONS

Numerical Index to AF Administrative Publications

		Paragraph
Section I	General	1 - 3
Section II	Index to AF Regulations	4 - 5
Section III	Index to AF Letters	6 - 7
Section IV	Index to AF Manuals	8 - 9
Section V	Index to AF Tables of Organization and Equipment	10
Section VI	Index to AF Tables of Allowances	11

Figure 2—5. Publications (AF Regulation).

The Numerical Index to AF Administrative Publications is AFR 5-2 (Figure 2-5).

Publications issued by the Air Force which provide technical instructions and information pertaining to the operation and maintenance of Air Force aircraft and equipment are referred to as "technical publications."

5. AIR FORCE TECHNICAL PUBLICATIONS

General

When a person buys a new commercial appliance, car, or other mechanical contrivance, a little folder of operating and maintenance instructions is usually furnished by the manufacturer. These instructions are supplied in order that the user may obtain the greatest possible satisfaction from his purchase. The manufacturer goes to considerable work and expense to provide the user with printed information about his product.

In the same way, the Air Force is vitally interested in seeing that its equipment functions properly and is maintained as efficiently as possible. It is a tremendous task to see that all of the various types of Air Force equipment, including the new gigantic aircraft, the engines, the radio and radar equipment, and all the other types of items necessary for the successful operation of a world-wide air force, are operated and maintained efficiently and economically.

The Air Force, like the manufacturer of a commercial appliance, provides printed instructions for use in connection with its equipment. These printed instructions, i.e., manuals, handbooks, sheets, charts, etc., which provide technical instructions and information pertaining to the operation and maintenance of Air Force aircraft and equipment, are referred to as "technical publications." They are published and distributed by the Air Materiel Command for and in the name of the Secretary of the Air Force, in accordance with AF Regulations 5-1, 5-10, and 20-1.

With so many types of equipment affected, it can be readily understood why there must be a technical publications system, a well organized and planned procedure whereby information is obtained, compiled, published, and distributed to the particular Air Force activity which needs it. Years of experience have resulted in the adoption of the standard system outlined below (See Figure 2-6).

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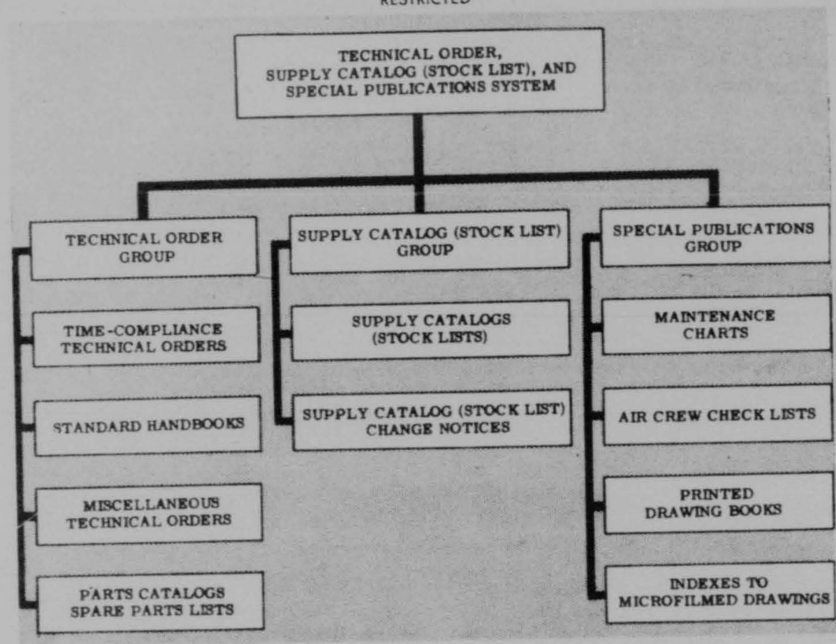

Figure 2–6. Major Groups and Types of Publications.

Major Groups

Three major groups, comprising appropriate types of publications, form the standard Air Force technical publications system. (See Figure 2-6):

Technical Orders (including applicable Air Force-Navy [AN] publications).

Supply catalog (stock list) publications.

Special publications.

Technical Orders, including Air Force-Navy (AN) publications and supply catalogs, normally are issued on loose leaf pages of standard size (8½ x 11 inches) to permit convenient assembly in uniform binders and placement in the prescribed technical publication files.

Special publications are issued in varied forms and sizes, depending on the intended usage. These technical publications normally supplement or implement the information and instructions. Typical examples of publications belonging to this group are the aircrew check lists and Air Force maintenance charts.

6. TECHNICAL ORDERS

The first of the three groups of technical publications includes Air Force technical orders, including Air Force-Navy (AN) publications which comprise a comprehensive group of publications issued to furnish Air Force personnel with general technical information on the use and operation of Air Force aircraft, equipment and accessories, and specific operating, maintenance, overhaul, repair, modification, storage, issue and inspection information on particular items of aircraft and equipment.

Instructions and procedures contained in Technical Orders are official Air Force directives and must be complied with as prescribed therein. Technical Order publications are readily identified by the prefix "T.O. No." to the assigned publication number.

Note: For purposes of uniformity and clarification, the term "technical order" when used in this publication embraces all publications bearing the aforementioned "T.O. No." prefix.

Air Force-Navy (AN) publications are published by joint agreement of the Air Force and the Navy Bureau of Aeronautics. The prefix "AN" indicates that the publication was prepared in accordance with Air Force-Navy aeronautical specifications. When applicable to Air Force aircraft or equipment, AN publications will be regarded as being identical in purpose with AF Technical Order publications.

Types of Technical Orders

The Technical Order group of publications consists of the following four general types:

Time-compliance Technical Orders.

Standard handbooks.

Miscellaneous Technical Orders.

Parts catalog (including spare parts lists).

A specific numbering system is employed to identify all publications belonging to the Technical Order group. The numbering system used is illustrated in the Table of Contents of T.O. 00-1-1, "Numerical Index of Technical Publications."

When only small quantities of equipment are purchased for Air Force use, commercial publications issued by the manufacturers sometimes are accepted in lieu of standard handbooks and parts catalogs. These commercial publications are given Technical Order numbers and are available only to activities operating or maintaining the equipment involved.

Time-compliance Technical Orders

Purpose. Publications of this type require compliance within specified time limits and provide for modifications of Air Force aircraft and equipment or furnish supplementary instructions covering inspection and operating procedures. In many cases time-compliance technical orders contain specific instructions for operating personnel; in such cases, commanders will be responsible for insuring that operating personnel become familiar with the contents of publications of this nature.

Types. Time-compliance Technical Orders are grouped according to the importance and urgency of the instructions contained therein. Notes are employed immediately preceding the text to specify when and by whom compliance will be effected and the degree of urgency. Time-compliance Technical Orders include the following types:

Immediate action Technical Orders.
Immediate attention Technical Orders.
As soon as possible Technical Orders.
As soon as practicable Technical Orders.

Format. Time-compliance Technical Orders are published without a title page under the heading "Department of the Air Force, Headquarters, United States Air Force, Washington," and bear the closing phrase "By Order of the Secretary of the Air Force." Borders or identification notes printed in red are used to focus attention on the more urgent time-compliance publications.

Immediate-action Technical Orders. Immediate-action Technical Orders are identified by the use of a border of red "X's" and the words "Immediate Action" printed in red. The border indicates that a red "X" must be entered in the "status today" columns on AF Forms 1-A, 1-AG and 41B. Immediate-action Technical Orders contain emergency instructions applicable only to aircraft and aircraft components, the urgency of which is such as to require the immediate grounding of the aircraft pending compliance. They specify that the work outlined therein is to be accomplished immediately. Such Technical Orders do not contain instructions of a continuing nature, such as a requirement for subsequent periodic inspection. The publication of immediate-action Technical Orders is expedited by HQ AMC as the instructions contained therein are of vital importance. Such Technical Orders will be disseminated to all affected personnel without delay.

Immediate-attention Technical Orders. Immediate-attention Technical Orders are readily identified by the words "Immediate Attention" printed in red at the top and bottom of the first page. They are similar to immediate-action Technical Orders except that they normally do not require work, except placarding for the pilot's information or marking of flight instruments. When applicable to aircraft, these Technical Orders contain important informational, operational, precautionary, and restrictive instructions on conditions which seriously affect the safety of flight of the aircraft involved, but which do not require its grounding.

Immediate-attention Technical Orders are also used for extremely urgent modifications or inspection instructions pertinent to personal equipment, chemicals, vehicles and other items of ground and communications equipment, as an immediate action category bears no "grounding" significance when applied to such equipment. The publication of immediate-attention Technical Orders is expedited by HQ AMC as the instructions contained therein are of vital importance. Such publications must be disseminated to all affected personnel without delay.

As-soon-as-possible Technical Orders. As-soon-as-possible Technical Orders are printed with a border of diagonal red lines which indicates that a red diagonal must be entered and carried in the "status today" columns on AF Forms 1A or 1AG and 41B until compliance has been effected. These Technical Orders provide instructions pertaining to aircraft and components and specify compliance as soon as possible but not later than a specified inspection period. Such Technical Orders normally require correction of defects affecting the flying efficiency of aircraft which are not sufficiently urgent or dangerous as to warrant grounding the affected aircraft. Compliance with this type of Technical Order is necessary before the aircraft can be considered to be in first class mechanical condition. Pending compliance with such Technical Orders, an "exceptional release" is required to clear the aircraft for flight. Such publications must be disseminated to all affected personnel without delay.

As-soon-as-practicable Technical Orders. As-soon-as-practicable Technical Orders contain instructions which specify that the work to be accomplished may be performed within broader time limits than those specified for the more urgent classes of time-compliance publications. They require compliance when accomplishment will not interfere with flying schedules, unless local conditions necessitate more urgent action, or when the affected aircraft or equipment is undergoing overhaul or other repairs. This type of Technical Order contains instructions to remedy defects that are not necessarily serious, but which must be corrected to forestall possible future malfunctioning or failure. They currently bear no distinguishing format or symbols to afford ready identification and can be identified only by reading the compliance requirements appearing beneath the titles.

Other Types. In some instances, Technical Orders are published to provide instructions for modification of equipment; they may cover the installation of special equipment; they may deal with equipment for the performance of special duties and missions which are not normally made by all aircraft or equipment of the same model or series. Compliance, in such instances, is effected only upon issuance by Hq., Air Materiel Command, of additional instructions directing the work to be accomplished on specific aircraft or equipment. Such Technical Orders can be identified only by reading the compliance requirement beneath the title (Figure 2-7).

Standard Handbooks

Purpose. Publications in this group contain basic instructions and information relating to operation, service, repair, and overhaul of Air Force aircraft and equipment.

Format. Standard handbooks are usually prepared by the equipment manufacturer in accordance with Air Force-Navy (AN) or AF specifications. These handbooks normally are issued with a full size title page bearing the assigned "AN" or "T.O." publication number, with the word "HANDBOOK" preceding the title. When a full size title page is used on a standard handbook, it is backed with a basic "A" page, followed by a series of pages numbered in lower case Roman numerals (i, ii, iii, etc.) containing the table of contents and illustrations of the equipment covered in the publication. In cases where the material in a

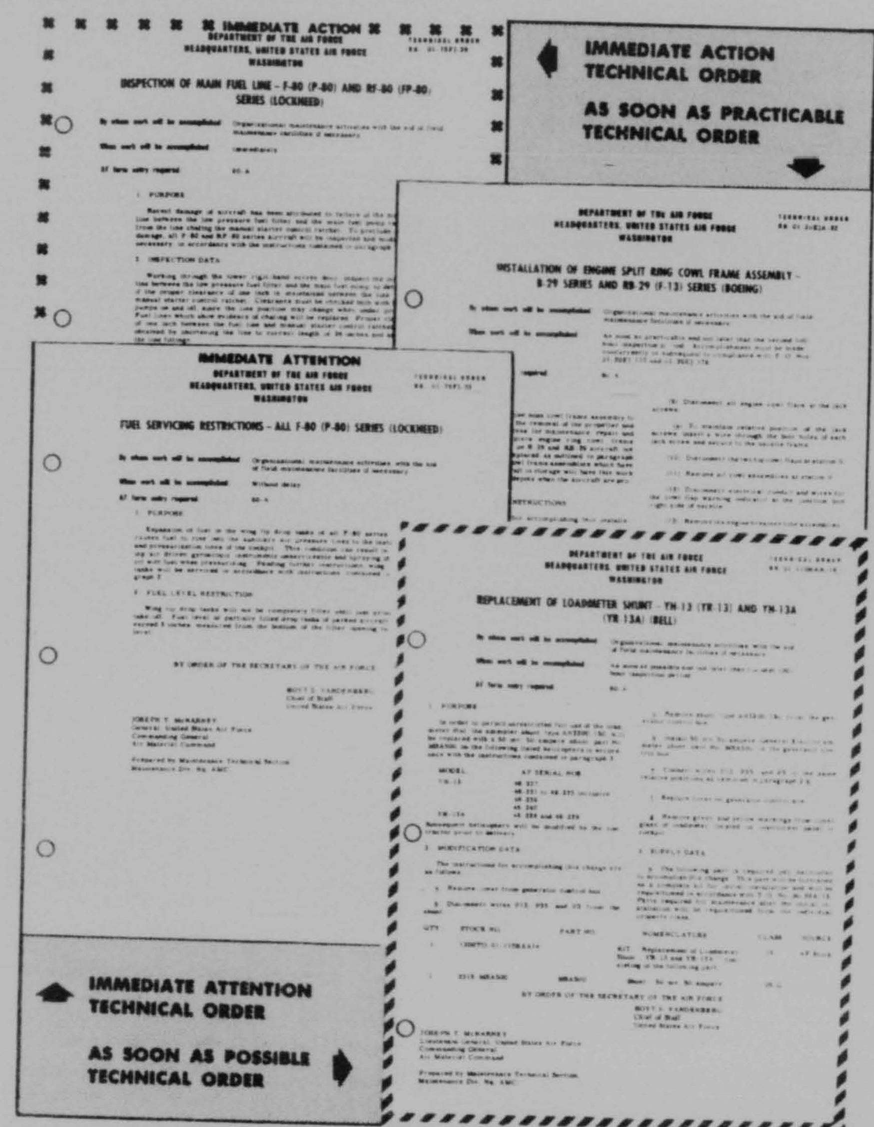

Figure 2-7. Time Compliance Technical Orders.

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standard handbook covers only one or two pages, the "A" page is omitted and a reduced size title page containing identical information is used preceding the text.

Types. Standard handbooks fall in one of the following two categories (aircraft handbooks and equipment handbooks):

Aircraft Handbooks. Aircraft handbooks are issued for each series of standard A aircraft to meet the needs of operating and service personnel. Every effort is made to publish these handbooks concurrently with the delivery of the aircraft to the service. Aircraft handbooks consist of the following types of publications:

a) Flight operating instructions contain all essential information required by the pilot and flight crew to operate the airplane, including all accessories and equipment, under all operating conditions. However, instructions pertaining to the basic technique of flying, or the detailed operation of armament, communicating or other operational equipment are omitted. Any unconventional characteristics which the airplane may possess are clearly described, together with the appropriate countermeasures.

b) Erection and maintenance handbooks contain all essential information required by service personnel for field maintenance purposes to service and maintain complete airplanes. They also deal with such service and maintenance as can be accomplished by operating activities on engines, accessories, instruments and associated equipment while installed in the aircraft. These handbooks contain all maintenance instructions from minor adjustments, tests, and inspections to major disassembly and repair of the airframes and controls with the exception of structural repair, which is included in handbooks on structural repair.

c) Structural repair handbooks contain all essential information required for determining the extent of any damage to the aircraft and for its repair.

d) Inspection and maintenance requirements handbooks for use by inspectors, crew chiefs, mechanics, and other concerned personnel, are issued to insure that periodic inspections performed by such individuals meet established standards of thoroughness. These handbooks, which are being issued as rapidly as possible to replace the present aircraft inspection and maintenance guides, contain brief, concise lists of aircraft, engine and associated equipment items which are to be inspected at designated periods. They also contain information pertaining to the accomplishment of minor maintenance work. The information contained in these handbooks will replace that contained in the inspection section of the aircraft erection and maintenance handbooks and the equipment operation and service instructions handbooks.

e) Basic weight check list and loading data handbooks contain detailed weight and balance data for specific models of aircraft for use in the Handbook of Weight and Balance Data, AN 01-1B-40. General information pertaining to the AF system of weight and balance control of aircraft is outlined in Technical Orders of the 01-1B series.

Equipment Handbooks. Equipment handbooks, covering specific items of airborne and ground equipment, are issued to cover overhaul procedures and, when necessary, to provide operating and service instructions for these items of equipment. Equipment handbooks include the following types of publications:

a) Operation and service instruction handbooks provide instructions for operating, storage, service, routine maintenance and trouble shooting data of items of AF equipment. Complete handbooks of this type are issued for items of ground equipment, and for the more complicated airborne accessories and systems, such as remote control turret systems, which cannot be adequately covered in the standard handbooks for aircraft.

b) Overhaul instruction handbooks contain information for the disassembly, inspection, repair, reassembly, and testing after overhaul of AF equipment other than aircraft.

Miscellaneous Technical Orders

General. Publications of this type are issued for specific purposes to disseminate information and instructions not provided for in standard handbooks. Generally speaking, these Technical Orders cover a wide range of

subjects which, in some instances, cannot be readily grouped into distinct classes. Miscellaneous Technical Orders include indexes of various kinds, lists of applicable publications for individual aircraft models, kits and sets of equipment publications, radio facility publications, parts interchangeability publications, engineering manuals, and technical orders which explain systems and procedures governing technical publications, classification of equipment, maintenance, overhaul and supply of AF equipment.

Format. Miscellaneous Technical Orders are issued with full size title pages and "A" pages, except when the material in such publications is limited to a few pages and when a reduced size title page may be advantageously used. Arrangement of data in such Technical Orders varies in accordance with the intended purpose of each publication and usually does not follow any prescribed specifications such as those established for standard handbooks.

Indexes. Indexes are issued to familiarize AF personnel with the availability and status of technical publications. The basic index, covering the entire technical publications system covered herein, is T.O. 00-1-1, Numerical Index of Technical Publications, more fully described later in this section, and referred to hereinafter as the "numerical index." Separate indexes or lists are issued to cover publications relating to specific types of equipment such as communications, armament, vehicles, marine, and motorized equipment.

Lists of Applicable Publications. Lists of applicable publications for individual aircraft series are issued and augmented by cumulative supplements to enable AF personnel to select and become familiar with technical publications pertinent to assigned aircraft. The applicable publications indicated in these lists are arranged numerically with important supplementary data denoting the type of each publication, time and place for any required compliance action, the forms on which entries are required, periodic inspection periods, and the serial numbers of aircraft affected. Lists of applicable publications are effectively employed as check lists for compliance with Technical Orders and also assist in determining publications required for limited technical publication files.

Kit Publications. Kits and sets of equipment Technical Orders, commonly known as the "00-30" series, itemize components of kits and sets of equipment which are prescribed in equipment authorization tables (Tables of Organizational Equipment and Tables of Allowances).

U.R. Digest (T.O. 00-10-1). The U.R. Digest contains data regarding corrective actions for unsatisfactory conditions reported by service activities when such actions are not mandatory but are of value to the service. The information is arranged under appropriate subjects with brief explanations of the difficulty, its cause, and the recommended corrective action.

Radio Facility Publications. Radio facility publications are issued primarily to make available to pilots, navigators, and radio operators, current information on radio aids to navigation. This type includes the AF Radio Facility Charts, T.O. 08-15-1, and AF Radio Data and Flight Information, T.O. 08-15-2.

Microfilm Drawings. T.O. 00-5-4, "Explanation of the Distribution and Numbering System for Microfilm Indexes," is a miscellaneous Technical Order. The indexes referred to therein, however, are special publications (Figure 2-8).

Parts Catalogs and Spare Parts Lists

Purpose. Parts catalogs are issued for the primary purpose of identifying parts and to act as aids in the requisitioning of parts for AF aircraft and equipment. A similar purpose is served by spare parts lists which are issued, in most instances, to cover communications equipment.

Contents. Parts catalogs usually contain a section providing a numerical parts list and another section outlining these data by group assemblies with illustrations of such assemblies. Complete nomenclature and part numbers are provided in these catalogs. In most instances the part numbers shown are those of the manufacturers. Spare parts lists are less comprehensive publications containing a detailed listing of items with assembly designations, descriptions, and manufacturer's part numbers.

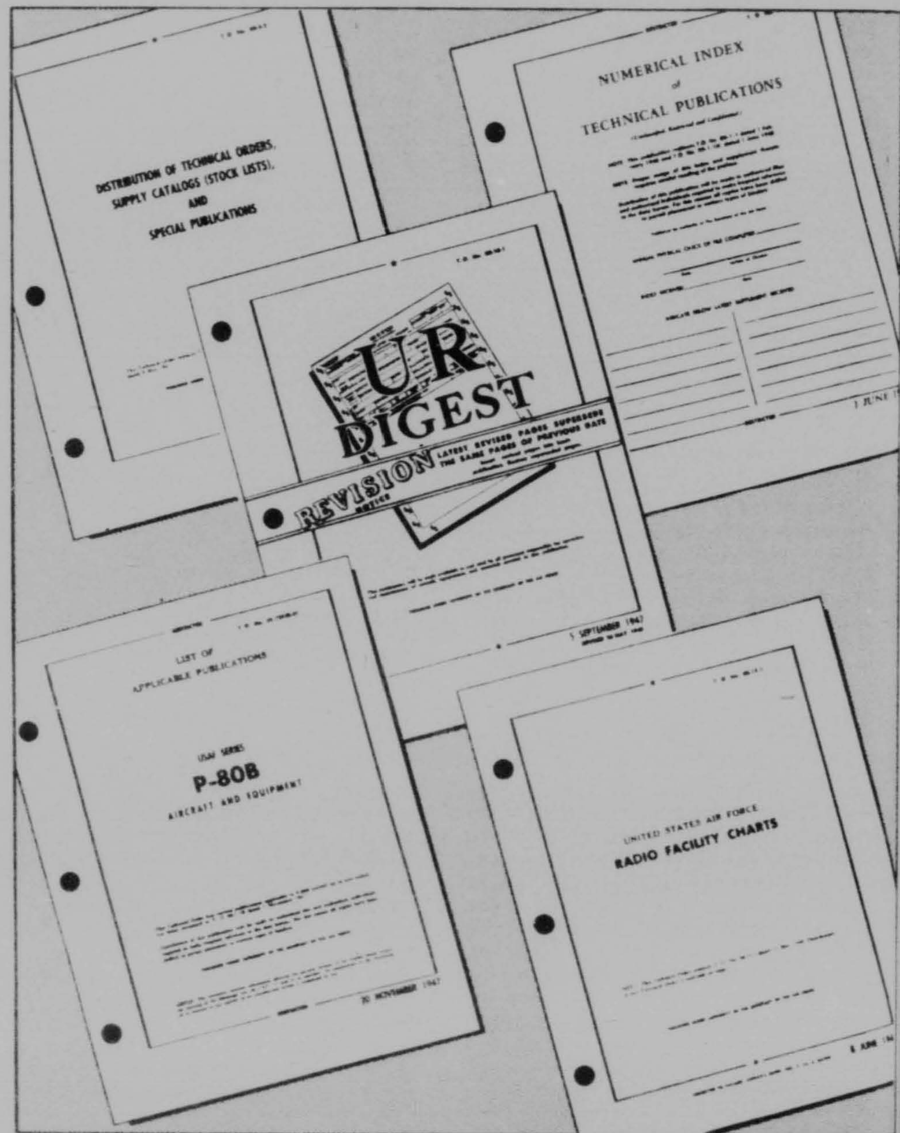

Figure 2–8. Miscellaneous Technical Orders.

Format. Parts catalogs and spare parts lists are published with title pages and "A" pages similar in design to those employed for standard handbooks, except that the words "Parts Catalog" or "Spare Part List" precede the names of the equipment covered by these publications. Data contained in these publications are arranged in tabular form.

Supply Catalogs (Stock Lists)

The purpose, contents, and use of Air Force supply catalog will be discussed in the section titled "Armament Supply."

7. SPECIAL PUBLICATIONS

General

Publications in this group are issued to implement or sometimes supplement information or procedures contained in technical orders. In most instances, a special publication is a more convenient medium for usage on the job, as it is designed in a size and form to serve best the intended purpose.

Principal Types

Air Crew Check Lists. Air crew check lists, printed on 5 inch x 8 inch cards for convenient usage, are issued primarily for transition training purposes. Separate check lists of this type are issued for pilots and other crew members. All such check lists are published under the authority of AF Regulation 62-2.

Indexes of Microfilm Drawings. Original engineering drawings of aircraft, engines and accessories are reproduced on microfilm for limited distribution to USAF activities. Indexes are published and are made available only with sets of microfilm drawings in accordance with AF Regulation 5-17. Instructions on the use of microfilms and microfilm equipment are contained in T.O. 10-1-135. An explanation of the methods used for indexing, requisitioning, and distributing microfilm drawings is contained in T.O. 0-5-4.

Printed Drawing Books. Printed drawing books are bound reproductions of engineering drawings in 22 x 34 inches and 17 x 32 inches size, covering certain types of aircraft or aircraft accessories manufactured by a specific contractor. Procurement and distribution of new printed drawing books and revisions thereto is no longer being made.

AF Maintenance Charts. Maintenance instruction charts and engine limits and lubrication charts are charts 22 x 34 inches and 20 x 30 inches respectively, for use by maintenance personnel in the maintenance of AF equipment and for instructional purposes. They are available upon requisition only. Procurement of new engine limits and lubrication charts is no longer being made.

Changes to Publications

Methods Employed. Changes to existing Technical Orders and special publications are made either by means of revisions, reissues, supplements, appendixes or addenda. Use of loose-leaf format permits efficient, economical, and speedy revision of many types of technical publications within the system. Removal of publications from active status is accomplished by rescission or replacement.

Indexing and Numbering

Indexing. General. Official listing of active Technical Orders, supply catalogs (stock lists) and special publications is accomplished in the numerical index, which is issued at extended intervals and augmented every two weeks by a cumulative supplement. The numerical index and supplements thereto provide a ready reference to existing publications and are used in maintaining publication files in current status.

Note: To determine what publications are active and available, it is necessary to use only the current cumulative supplement in conjunction with the basic numerical index.

Basic Numerical Index (T.O. 00-1-1). The basic numerical index lists all active publications within the system which have been distributed to AF activities prior to the publication date shown on the title page of the index. When reissued, the basic numerical index is revised to delete listings of rescinded or replaced publications and to incorporate data concerning publications distributed since the previous issue of the basic index.

Supplements. Supplements of the numerical index contain lists of newly issued, revised, reissued, superseded, replaced, and rescinded

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publications. All such supplements are cumulative and are numbered T.O. 00-1-1A, -1B, etc. Cumulative supplements also list all publications, including revisions and reissues, scheduled for future distribution.

Numbering

General. Numbers are assigned to Technical Orders, supply catalogs (stock lists), and some categories of special publications for purposes of ready identification, indexing, referencing, and filing. The assigned numbers follow the appropriate identifying prefix, such as "T.O. No." for technical orders, "S" for supply catalogs (stock lists), "C" for AF maintenance charts, and "MF" for microfilm drawing indexes.

Technical Orders. Technical Orders, including AN publications, are assigned numbers of two or more parts (usually three parts), separated by dashes. The first part of the number identifies a particular section of publications in the numerical index, i.e., "01" indicates Technical Orders in Section 01, "Aircraft Publications." The second part of the number is related to the series and subseries to which a Technical Order is assigned for proper grouping of equipment by type, system, model, or manufacturer. Alphabetical letters are added to the second part of the number to segregate further the equipment covered. The final part of the number is employed to list numerically, Technical Orders within a given series or subseries, i.e., -1, -2, -3, etc. A suffix letter is added to this part of the number when supplementary information is issued as a separate publication.

Aircraft Inspection and Maintenance Publications. Guides. Existing aircraft inspection and maintenance guides are basically numbered "00-20A" to indicate the relationship of these publications to T.O. 00-20A, "USAF Aircraft and Related Airborne Equipment Inspection and Maintenance System." This basic number is followed by the aircraft series number applicable to each guide. For example, the inspection guide for B-29 aircraft is numbered "00-20A-B-29." A prefix is not employed for these publications.

Inspection Handbooks. In the future, inspection and maintenance requirements will be published in the form of standard handbooks in the applicable aircraft Technical Order series. The number to be assigned will normally be the "-6"; for example, the inspection and maintenance requirements handbook for the B-36 aircraft is numbered "T.O. 01-5FUA-6."

AF Maintenance Charts. Maintenance charts are numbered in a manner similar to Technical Orders, except that the prefix "C" is used instead of "T.O. No."

Indexes of Microfilm Drawings. Microfilm drawing indexes are numbered in the same manner as Technical Orders, except that the prefix "MF" is used to distinguish this type of publication from standard Technical Orders.

Security Classification

Technical Orders, supply catalogs (stock lists), and special publications are published as unclassified, restricted, or confidential documents. The classified publications (restricted and confidential) are appropriately marked on their title pages and, when required, on all subsequent pages of such publications. Publications listed in the numerical index, and supplements thereto, are unclassified except when the word "RESTRICTED" or "CONFIDENTIAL" appears in bold face type immediately following the title of the publication.

Classified publications in file which have been downgraded are not reprinted and distributed merely to reflect a change in classification. Revisions or reissues to such publications, however, will reflect the current classifications. Confidential publications must be maintained in separate file and safeguarded in accordance with the provisions of AR 380-5.

Rescinded and replaced (or superseded) publications, which are no longer required, will be removed from the file and disposed of as follows:

If unclassified, dispose of in accordance with instructions of the local salvage officer.

If classified, destroy in accordance with the provisions of Army Regulation 380-5.

Note: Additional information on technical publications can be found in T.O. 00-5-1.

The Air Force technical publications are listed numerically in T.O. 00-1-1.

The alphabetical Index of Technical Publications is T.O. 00-1-2.

CHAPTER 3—ADMINISTRATIVE DUTIES OF ARMAMENT OFFICER

SECTION I—ARMAMENT OFFICER'S DUTIES

1. GENERAL

The Air Force armament officer's primary responsibility with respect to armament is that tactical airplanes shall at all times be fully ready to perform their missions under full military load. In order to fulfill his primary responsibility, the armament officer must:

Educate personnel in their command in the importance of safe operation, preventive maintenance, and training to perform their prescribed preventive maintenance duties regularly and properly.

Requisition all correct official Department of the Army and Department of the Air Force publications dealing with maintenance and operation of equipment under their control and make these publications available to personnel responsible for carrying out these instructions.

Requisition all authorized tools, equipment, supplies, and parts required to accomplish preventive maintenance services.

Schedule periodic preventive maintenance services for equipment under their control as specified in official publications concerning the equipment, allowing adequate time for the completion of these services by responsible personnel.

Periodically inspect materiel, including the tools, supplies, and parts needed for maintenance operations. (This is to insure that operation of equipment and performance of preventive maintenance services thereon, including handling, packing, transport, and storage, conform with current regulations and standard practices.)

Prevent the abuse of materiel under their control. (Evidence of abuse must be investigated and appropriate action taken thereon.)

Prevention of abuse of materiel is one of the most important responsibilities of the armament officer. Some of the more common abuses he must guard against are:

Improper, careless, or negligent use or operation of materiel.

Lack of lubrication, overlubrication, or use of unauthorized lubricants.

Lack of inspections.

Deferred maintenance, including lack of proper servicing and adjustments.

The attempting of repairs by unqualified personnel or by use of improper or inadequate tools, parts, and equipment.

Rather than explain each responsibility separately, this section and those following will explain in general the information that must be known before an Air Force armament officer may fulfill his responsibilities.

2. DUTIES OF AN ARMAMENT OFFICER

The armament officer has many duties, and among the more important he does the following:

a) Supervises loading of bombs into bomb-racks and ammunition into ammunition boxes of combat aircraft. (It is now the normal function of the armament section to transport bombs or other ammunition from the ammunition dump to planes. Transportation, fusing, and delivery of bombs and belted ammunition from the dump to airplane is also exclusively an armament function. At the airplane, the armament crew assumes charge, and arms the planes with the bombs and ammunition that have been brought to the loading point, that is, the plane.)

b) Acts as a special staff officer to the commander, keeping him and the operations officer advised as to:

Serviceability of armament.

Performance of armament under varying climatic conditions.

Status and availability of armament equipment and supplies.

Logistical data concerning armament equipment.

Probable errors in bombardment and gunnery.

c) Maintains proper and accurate records of expenditure of ammunition, flares, bombs, and other ordnance supplies; of status of equipment, and of bombing and gunnery scores. (In some units, these records may be kept for the armament officer by the ordnance section, but in either case they are closely coordinated with those of the operations officer. Such records are periodically forwarded through channels to higher headquarters; their importance lies in the fact that the maintenance of an adequate ammunition reserve will depend upon the accuracy with which they are kept and the promptness with which they are forwarded.)

d) Keeps a status board or chart showing at all times the dates upon which inspections of aircraft armament equipment have been completed.

e) Sees that all unit armament supplies are properly and promptly procured and distributed.

f) Procures and keeps up to date files of technical publications bearing upon maintenance, operations, and storage of armament and chemical equipment.

g) Maintains all necessary records, reports, files, and correspondence bearing upon work of armament and chemical sections.

h) Supervises training of air crews in use, and of air and ground crews in maintenance, of all armament equipment.

i) Procures, equips, and supervises ranges for gunnery and bombardment practice, and rigging of tow targets.

j) Schedules use of gunner, bombardment, and small arms ranges.

3. DUTIES OF A UNIT GAS OFFICER

The unit gas officer must:

a) Train the required number of chemical NCO's for the unit.

b) Train all unit personnel in all matters pertaining to defense against chemical attack, including:

Gas mask drill.

Detection and identification of chemical agents.

Detection and posting of gassed areas.

First aid for chemical casualties.

All methods of decontamination, including decontamination of planes and other equipment.

c) Give necessary specialized instruction to personnel detailed as gas sentries.

d) Prepare standard operating procedure for defense against chemical attack.

e) See that an adequate system of gas alarms and gas-proof shelters is maintained.

f) Maintain a constant check on status of supplies of chemical protective equipment.

g) See that chemical warfare equipment is properly used.

h) Supervise administration of the chemical section, including preparation and forwarding of all necessary reports and correspondence.

i) Maintain necessary records and files.

4. DUTIES OF AN ORDNANCE OFFICER

The duties of the ordnance officer include:

a) Storage and supply of completely assembled bombs, pyrotechnics, and belted ammunition to the squadron. (Within this responsibility rests the proper loading of bomb components for required complete rounds, and assembly and fusing of rounds at the bomb fusing point; within it rests also the delivery of complete assembled rounds to aircraft personnel [armament] at the bomb service point.)

b) Daily compilation of the status of ammunition report. (As has been pointed out, the armament officer, within whose duties lies the supervision of bombardment practice, has his own reports to coordinate with those of the operations office. All data on ammunition expenditure must be accurate and must be rendered promptly if an adequate supply for planned operations is to be available.)

c) Estimate of ammunition requirements for forthcoming operations. (This duty requires the closest coordination with the operations officer, since operations and intelligence alone have a preview of scheduled events.)

d) Inspection, repair, and maintenance of all ordnance materiel within his command. (Ordnance materiel is that materiel that is procured and issued by the Ordnance Department.)

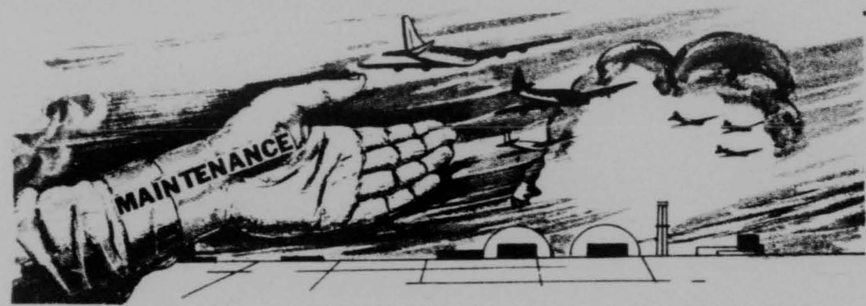
e) Maintenance of records, correspondence, forms, and files relating to ordnance matters and to training of ordnance personnel.

f) Cooperation and coordination with the armament and chemical warfare officers.

g) Serving as technical adviser to the commander on ordnance matters, including supply, storage, use, operation, and performance of ordnance materiel.

h) Supervising disposal of unexploded bombs in the areas.

SECTION II—MAINTENANCE



1. GENERAL

It is the purpose of the following to introduce to the student the fundamentals of maintenance and to acquaint him with the Air Force maintenance system in order that he may better understand his maintenance responsibilities.

Maintenance is the normal upkeep and preservation of equipment which may be necessary from time to time because of usage, wear and tear, or deterioration by the elements.

Every member of the military forces has a definite maintenance responsibility. Maintenance responsibilities vary, from preventive maintenance operations employing highly specialized repair and reconditioning techniques, to the supervision and inspection necessary to insure that equipment is ready for use. Personnel operating equipment, technical maintenance experts, and commanders of all echelons must conscientiously strive to prevent the deterioration of and to insure the efficiency of all military equipment.

Efficient maintenance dictates that the various maintenance operations which must be performed on each item be allocated to certain personnel in pre-established places.

Where and by whom any given operation is performed is determined by the facilities, nature of repairs, time available, skill of personnel, availability of tools, parts, and the need for mobility.

The system requires that all personnel receive sufficient technical training to perform their prescribed maintenance functions and that all organizations be provided with sufficient personnel, equipment, tools, test equipment, supplies, and parts to accomplish their maintenance mission.

To define responsibility and have a standardized system, the Air Force has classified maintenance into echelons that conform to the organization and mission of its units.

2. USAF SYSTEM OF ORGANIZATIONAL MAINTENANCE

Organizational maintenance will normally consist of preventive maintenance operations performed by the user, wearer, operator, or operating crews of the equipment, or by specially trained personnel of the using organization. This includes proper care, use, cleaning, operation, preservation, servicing, routine and periodic inspections, minor repair not requiring disassembly of subassemblies, and accomplishment of instructions as directed in Technical Orders and other applicable directives.

3. USAF SYSTEM OF FIELD MAINTENANCE

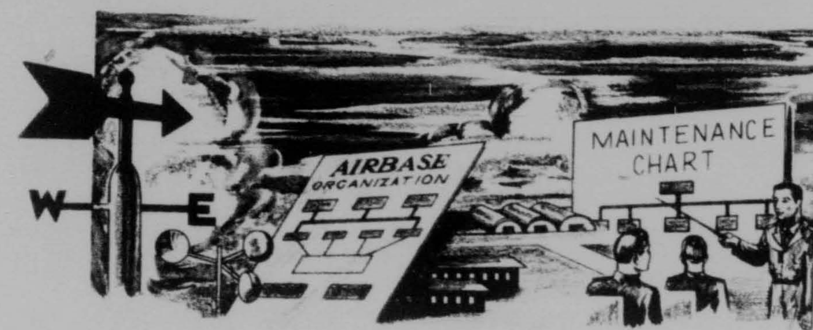
Field maintenance consists, primarily, of corrective maintenance that is beyond the scope of the using organization and is normally performed by personnel of the air base.

This includes repairs requiring fixed shops or ground mobile equipment, replacement of major unit assemblies, fabrication of parts, accomplishment of instructions as directed in publications, and such assistance to lower echelons as is necessary.

4. USAF SYSTEM OF DEPOT MAINTENANCE

Depot maintenance includes all operations necessary to restore worn or damaged equipment to a serviceable condition and the periodic overhaul of assemblies, accessories, and auxiliary items as prescribed in directives; replacement and repair of auxiliary equipment; fabrication of such parts as may be required in emergency; and technical advice and assistance on maintenance matters to USAF activities. Depot maintenance may be limited or specialized as directed by higher headquarters. It is normally performed by the air depot.

SECTION III—FACTORS AFFECTING MAINTENANCE



1. GENERAL

In some organizations for maintenance there have been no T O&E's published because of variable factors affecting this type of organization. The most important of these factors include: weather and climate, mission of the base, physical plant of the base, experience of personnel, and tools and equipment.

2. WEATHER AND CLIMATE

There are several weather and climatic conditions which affect the efficiency of the operation of equipment as well as the efficiency of maintenance operations. Among these are arctic, desert and tropical conditions.

In arctic operations, the efficiency of the equipment is reduced by low temperatures causing congealing of lubricants and by reduced capacity of storage batteries. In addition, the efficiency of maintenance personnel is reduced. It is necessary to provide elaborate shelter, clothing, and heating equipment, for sustained work is impossible under exposed arctic conditions.

In tropical climates, the main problems are accelerated corrosion and deterioration of equipment and reduction of efficiency of personnel due to the high heat and humidity.

In desert conditions, the main problems are the rapid failure of moving parts due to the abrasive action of sand and dust and the reduced efficiency of personnel in extreme heat.

3. MISSION OF THE BASE

Air Force bases are organized so that they may carry out most efficiently their particular functions; there will necessarily be organizational differences to meet the specific re-

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quirements of their mission. The general classification of wing bases are combat or air transport, training, and depot.

4. PHYSICAL PLANT OF THE BASE

Physical facilities of the base provide a plant in which assigned work is accomplished. The layout of these physical facilities has a direct and important bearing on the efficiency with which work is accomplished. A poorly laid out plant is a problem because correction is always difficult and sometimes almost impossible. New construction, extensive relocation, or modification of existing buildings is usually out of the question. In general, it is necessary to use existing facilities as they stand, assigning functions, consolidating activities, and localizing to improve maintenance efficiency.

5. EXPERIENCE OF PERSONNEL

The fourth factor affecting maintenance is the experiênce of personnel. Development of adequate personnel begins with the selection of personnel after they have successfully passed the evaluation and proficiency tests. They should be selected for specific duties and assignments, and every effort made to utilize previous experience. Additional training will be made available by means of technical service schools and by on-the-job training. Supervisory training involves other and more complex factors, and is normally best given by classroom methods, personal instructions, and by example. Good operation provides for continuous evaluation and training.

6. TOOLS AND EQUIPMENT

Another element consists of adequate tools and equipment, and is a mandatory requirement if quality work is to be accomplished. Tools, tool equipment, and test equipment are allocated to the various types of organizations in accordance with authorized items. Tools and tool equipment, including test equipment, are generally considered as being divided into two groups, common and special. In most cases, these items are grouped in standardized sets and authorized for issue in supply catalogs or other official supply publications. Special tools for using organizations are closely allied to the major item to which they apply and are listed in T O&E or supply catalogues in conjunction with spare parts and accessories applicable to the major item.

The relationship of supply and maintenance cannot be overemphasized. The most qualified maintenance personnel in the Air Force may be available but unless the spare parts or maintenance supplies are available the specialized mechanic is useless. The converse is likewise true. Tons of spare parts or equipment in need of repair may sit idle for the lack of maintenance personnel. More than one-half of the items supplied by the Air Force and Army are those required for the maintenance of our equipment.

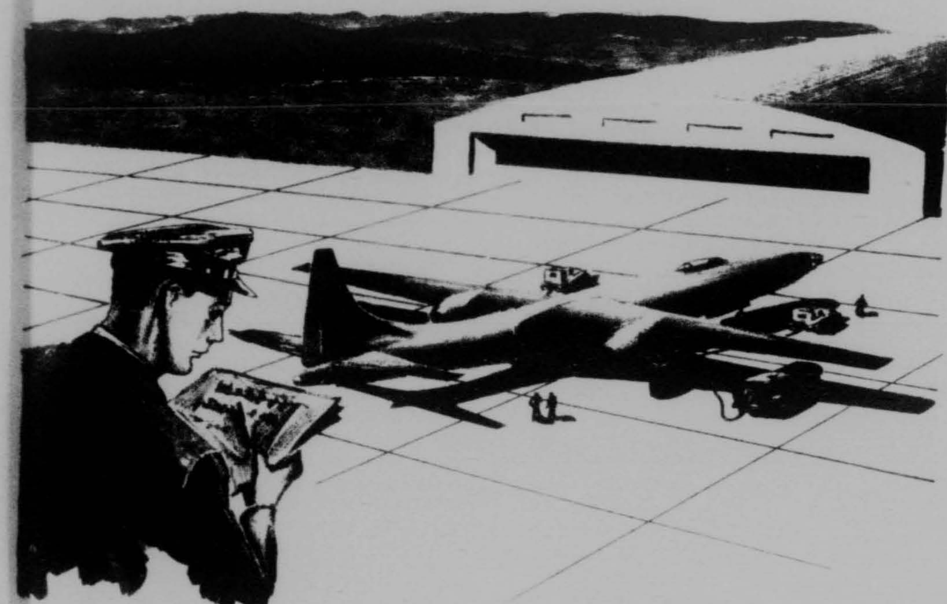
The major objective in building a maintenance organization is to provide a basis by which management (commanding officer) and supervision (armament officer) can effectively utilize the personnel, equipment, and facilities under their control to accomplish the:

Prompt return of unserviceable material to a serviceable condition.

Preventive maintenance inspections as required by publications.

Emphasis should be placed on good housekeeping, safety, security, fire prevention, records and reports, and training.

SECTION IV—AIRCRAFT MAINTENANCE



1. GENERAL

Since most of the air armament officers will be assigned to tactical organizations and be responsible for organization maintenance on aircraft, we will discuss the inspection and maintenance system as devised by the Air Force. This system is known as the "USAF Aircraft and Related Airborne Equipment Inspection and Maintenance System" and is explained in Technical Order 00-20A. This system provides the basic means of maintaining the highest possible percentage of aircraft in readiness for flight. This system operates by the use of maintenance record forms, Technical Orders (directives), inspection and maintenance guides (when applicable), and periodic inspections.

2. PREVENTIVE MAINTENANCE

Preventive maintenance is the regular periodic servicing and systematic detection and correction of failure in equipment by the operators and maintenance personnel. This includes a system of checks, inspections, and services performed on materiel to insure that it is kept in top operating condition, and to detect and correct minor troubles before they develop into major defects.

Preventive maintenance services, properly applied, keep equipment in the best possible operating condition; decrease the need for service maintenance, with a resulting saving of time, personnel, and expense; obtain the longest possible life of equipment and parts, thus reducing requirements for replacement parts; and assure the proper handling, packing, transport, and storage of equipment.

3. DUTIES AND RESPONSIBILITIES

Individuals. Individual users, wearers, or operators of equipment are responsible for the performance of all preventive maintenance

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services prescribed in the official Department of the Army and Department of the Air Force publications dealing with operation and maintenance of their equipment, and for the preparation of records and reports as specified in these publications.

Unit Mechanics of Using Organization. Specially trained maintenance personnel are responsible for the performance of all unit preventive maintenance services and for the preparation of records and reports on these services, as specified in the official publications concerning the operation and maintenance of their equipment.

Armament Officer. Establishes major purposes and objectives for the armament section, establishes departments for those groups which have related functions and provides supervision and inspection over all armament operations.

4. MAINTENANCE RECORD FORMS

These forms are used for the purpose of recording flying time, status of maintenance, operational fitness of the aircraft, and maintenance performed or required. They also include a record of all Technical Order compliances that are accomplished and required. Records transfers, depot inspection and repair or overhaul, damage to or replacement of major components, and total operating time.

5. TECHNICAL ORDERS

These are directives published by order of the Secretary of the Air Force for the purpose of issuing specific directives and technical information covering the operation, maintenance, storage, inspection, etc., of Air Force equipment and materials. Technical Orders are also published when the aircraft and related equipment requires modification. A modification is a specific authorized change in the design of assembly of an item of materiel to meet revised specifications or to correct defects. Modification of materiel is authorized only when it:

Is essential to the safety of personnel, or,

Prevents breakage or destruction of materiel, or,

Substantially improves effectiveness.

6. INSPECTION AND MAINTENANCE GUIDES

These guides contain pertinent inspection and maintenance data plus supplementary information for inspectors, crew chiefs, mechanics, and other interested personnel. The information in the Guide summarizes the more detailed instructions incorporated in the Technical Order. These guides are gradually being replaced by a Technical Order titled "Aircraft Inspection and Maintenance Requirements Technical Orders."

7. PERIODIC INSPECTIONS

The periodic inspections required for all USAF aircraft are: preflight, daily, 25-hour (minor), 50-hour (major), 100-hour (major), 200-hour and subsequent (major). A new system of inspection periods has been established and will gradually be adopted as the new Aircraft Inspection and Maintenance Requirements Technical Orders are issued. The above periodic inspections will be disregarded and the inspection periods in the new Technical Orders will be followed.

To insure that the quality of inspection and maintenance being performed is adequate, a continuous observation and evaluation of the periodic inspections must be conducted.

8. TYPES OF AIRCRAFT MAINTENANCE

To enable unit commanders to meet their objectives efficiently by adopting the method of accomplishing inspections most applicable to their local facilities and assigned personnel, one of the following listed methods will be utilized:

Crew chief method.
Production line method.
Consolidated inspection method.
Specialized inspection method.

9. CREW CHIEF METHOD

This method is by far the oldest and, in many respects, the most desirable system of maintenance since it allocates the responsibility for getting the job done to one individual. This method is the system whereby all periodic inspections of aircraft are made by

the crew chief and his assistants. This method is well adapted to situations when there are relatively few aircraft of various types and sizes. This system emphasizes individual merit and personal accomplishment; however, it has obvious disadvantages. Much training is required of a crew chief. Airplanes are becoming so complex that it is almost impossible for one man to master the complicated mechanism of all the equipment.

10. PRODUCTION LINE METHOD

This is an industrial system whereby periodic inspections of aircraft are accomplished by three or more inspection crews, each of which is assigned a specific set of tasks. The inspection crews are permanently assigned at a like number of fixed stations, especially equipped with tools, supplies, and equipment appropriate to the phase of the inspection assigned to the station. The aircraft are towed or pushed at established intervals to these fixed stations with their assigned inspection crews.

The advantages of a PLM is that inexperienced personnel may be utilized, since only one job has to be taught each individual on a line. It standardizes maintenance; by grouping tools together it provides maximum usage. It provides excellent on-the-job training.

The disadvantages are that it requires extensive planning and does not provide the spirit of responsibility and accomplishment attained by the crew chief method. PLM requires numerous maintenance hangars and is not very well adapted to maintenance in the field. It is adapted to maintenance of one type aircraft per production line only. It requires a maximum of good supervision. Due to the employment of work shifts there is much overlapping of responsibility.

11. CONSOLIDATED INSPECTION METHOD

This is the system whereby complete periodic inspections are made at appropriately-equipped docks or other fixed installations by a permanently-assigned inspection crew of aircraft mechanics, specialists, and trainees. Under the direction of a dock or station chief, these inspection crews accomplish all work involved by the inspections while the aircraft remains at the station. This system is especially adapted to very large airplanes where the installed equipment is complex and where there are no hangar facilities for performing maintenance under shelter.

12. SPECIALIZED INSPECTION METHOD

This is the system whereby major periodic inspections of aircraft are made at fixed station locations equipped with docks, work stands, testing apparatus, etc. Three or more roving inspection crews perform their phase of the completed inspection. With this system, the airplane, after being decowled and cleaned, is moved to the fixed station location where it remains until the inspection is completed. The specially-trained inspection crews move at intervals from one station to another and perform their respective tasks on a time schedule basis.

This system has the advantage of requiring a minimum of movements of aircraft since the work can be performed in dispersal areas. This system requires a large amount of transportation since each specialized crew is required to move from airplane to airplane. It appears that this method is the best suited for future combat units.

The preceding methods will be used for basic on-the-job training. Field maintenance can be performed by modification of the above method but is usually performed by specialized crews. However, in some cases, where the volume of work can sustain the production line, it is feasible to set up a production line for repairs.

Depot maintenance usually incorporates production line maintenance in the periodic overhauling of assemblies and accessories; but where the job order is small, it is often impractical to set up a production line.

SECTION V—UNSATISFACTORY REPORTS AND INSPECTIONS

1. REPORTS

All operations, maintenance, inspections, modifications, etc., are done according to the directives published by the Departments of the Army and Air Force. No changes or modifications may be done on equipment of the Air Force or Army without authority.

When an item appears to be unsatisfactory in design or material USAF Form 54 (Unsatisfactory Report) is submitted by the using or service organization. AFR 15-54 and T.O. 00-35D-54 will explain the purpose, scope, preparation, submission, etc., on the unsatisfactory report. Reports received from the field are analyzed and if a modification is justified, the head of the technical service concerned coordinates the publication and distribution of modification work order with the production of necessary parts, tools, or other materials required for the modification. Similarly, a technical order will be issued for Air Force materiel.

Note: Alterations or modifications of equipment may not be made except in compliance with an authorized modification work order or USAF Technical Order.

USAF Form 54 is the means whereby the operating units of the Air Force report to the Air Materiel Command failures of equipment, discrepancies in systems and procedures, or errors in forms and publications. These reports are initiated by any individual assigned or attached to the Air Force upon the first and all subsequent observations of an unsatisfactory condition falling within any of the following categories:

Unsatisfactory design.

Failure or malfunctioning of any item of government materiel or equipment used by the Air Force.

Defects due to faulty materiel, workmanship, or quality inspection.

Unsatisfactory maintenance or supply methods, systems, or forms.

Discrepancies in Technical Orders and malfunctions of the Technical Order distribution system.

Equipment authorized in tables of allowance which is unsuitable, inadequate, or excessive for the mission for which required.

Technical Orders of the 00-30 series prescribing equipment which is unsuitable, inadequate, or excessive for the functions for which required.

Deficiencies in Administrative methods.

Technical Orders of the 00-10 and 00-65 series contain a listing of all unsatisfactory reports that have been submitted along with corrective action to be taken.

To insure that the more urgent modifications are applied first, the Air Force has established a system of classification and markings on their Technical Orders to enable field and maintenance installations to schedule their modification work according to the urgency of each project.

The technical services have also established a system for the same purpose. The priority designation will appear on the printed modification work order and Technical Orders.

Special or emergency cases of malfunctioning or failure likely to result in grounding or holding aircraft out of commission, particularly where like equipment may be affected elsewhere, must be reported immediately by radio, wire, or telephone direct to the Commanding General, Air Materiel Command, Wright Field, Dayton, Ohio. This will include malfunctioning or failure disclosed by accidents or forced landings. In those cases where an accident occurred as the result of a failure, an appropriate comment to this effect must be included in the Unsatisfactory Report.

2. INSPECTIONS

Inspections of Army and Air Force materiel issued to organizations are conducted for the purpose of determining the condition of the materiel and detecting the cases of neglect and malpractice which reduce the life and operating efficiency of the item.

3. FORMAL INSPECTIONS

There are two kinds of formal inspections —"command and technical."

Command. Command inspections are conducted by all commanders to determine the condition and proper use of equipment and supplies, and to insure that the subordinate commanders are complying with established procedures and regulation.

Technical. Technical inspections are performed by technicaly qualified personnel under direct supervision of qualified officers, and consists of:

Complete examination and tests of materiel to determine its serviceability, completeness, and readiness for intended use.

Limited examinations to determine general serviceability, and to classify materiel as to general condition.

4. INFORMAL INSPECTIONS

In addition to formal inspections, frequent informal inspections of materiel will be made by the operators, users, or wearers as part of scheduled preventive maintenance services.

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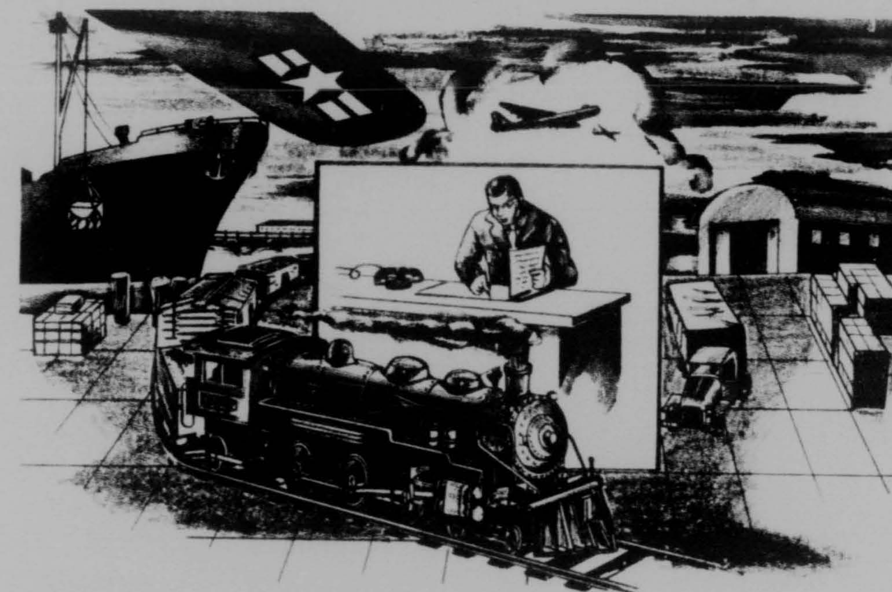
CHAPTER 4—ARMAMENT SUPPLY



SECTION I—INTRODUCTION

1. ARMAMENT SUPPLY—GENERAL

This section is devoted to basic supply subjects. It is not to be assumed, however, that it covers the entire supply field, or that it represents all the armament officer should know about supply. Basic supply is the minimum essential review necessary to prepare the student for additional supply instruction.–The armament officer will be faced with additional supply matters throughout his career in "Supply Planning, Logistic Estimate of the Situation, Administrative Instructions," and others.

Prior to the armed service unification in 1947, the Army Air Forces operated as an element of the War Department. Broad planning and coordination of supply was accomplished by the War Department; the Air Force was concerned primarily with Air Corps technical supplies. Today the situation is changed. Since the Air Force is an independent agency, it is responsible for planning and coordination of its own supply. In considering supplies used by the Air Force, one must take into consideration both Air Force technical supplies and supplies procured by the several other departments of our national defense organization, i.e., supplies used by the Air Force, such as clothing, tentage, general purpose vehicles, floating equipment, weapons, ammunition, etc.

The two basic classifications covering all such supplies used by the Air Force are: (1) common supplies, and (2) Air Force technical supplies.

Common supplies are defined as those supplies procured by the Department of the Army, Navy, or Air Force, but used by two or more of the armed services. They include food, individual clothing, tentage, etc. Air Force technical supplies are supplies whose procurement authority has been delegated to the Department of the Air Force, such as aircraft, aircraft assemblies, engines, aircraft maintenance parts, etc., and used exclusively by the Air Force.

SECTION II—AIR FORCE TECHNICAL SUPPLY

1. AIR FORCE TECHNICAL SUPPLY SYSTEM

The supply system used by the Air Force is one of the important factors in successful air operations.

The purpose of the following is to present the background of the Air Force technical supply system, and give the student a working knowledge of the Air Force supply classification and stock numbering system. By a study of the evolution of the technical supply system, it is believed that the system can more readily be understood.

During the first World War, Army aeronautics operated as the Aviation Section of the Signal Corps. Seven depots were established to furnish supplies for the airfield, airplanes, and air and ground crews in the areas assigned to them. Four were in the zone of the interior and three were outside the continental limits of the United States.

After the Armistice of 1918, the primary mission of these depots was the storage of vast quantities of material, much of which was worn out or obsolete. This material included equipment from Europe that was of little use to Army aeronautics. This all had to be identified, inventoried, and stored. At the same time, a change of personnel took place at the depots as many officers and enlisted men left the service and were largely replaced by inexperienced civilian employees.

In May, 1918, Army aeronautics was removed from the Signal Corps and came under the control of two new offices—the Bureau of Military Aeronautics and the Bureau of Aircraft Production. The depots operated under the Bureau of Military Aeronautics until June 1920, when they came under the newly created Air Service. In July, 1921, the Supply Division of the Air Service established a new section. This section was known as the Property Maintenance and Cost Compilation Section. This section was renamed the Field Service Section.

This remained until Congress created the Army Air Corps in July, 1926, to replace the Air Service.

After the Materiel Division of the Army Air Corps was established in October, 1926, the Field Service Section became one of its units.

During World War I, the prescribed methods and procedures for the accounting of Air Corps supplies were inadequate, so the various depot supply officers added their own methods. No two depots operated alike.

Thus, after the first World War the depots became overcrowded with surplus and obsolete items of equipment. The men who staffed the warehouses did not always know what property or how much was on hand. For several reasons, records of receipt and issue were inadequate; inventory was not up-to-date; too few persons knew how to properly identify and classify items of equipment. Items were identified, stored, and issued by nomenclature alone; and since nomenclature was not standardized, trouble was common.

2. USAF PROPERTY CLASSES

The first important step in the development of the Air Force technical supply system was the establishment of a system of property classification. The system adopted by the Air Service, later used by the Air Corps, and still used without extensive modification by the U. S. Air Force, had the virtue of combining a reasonable amount of simplicity with great flexibility. This was adopted and placed in operation in the depots in 1921. This system divided Air Corps supplies and equipment into twenty-nine major classes for convenience in

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS, UNITED STATES AIR FORCE
WASHINGTON

TECHNICAL ORDER
NO. 00-35A-1

23 August 1948

CLASSIFICATION OF UNITED STATES AIR FORCES EQUIPMENT AND SUPPLIES

This technical order replaces T. O. Nos. 00-35A-1, dated 18 June 1947 and 00-35A-1A, dated 18 November 1947.

SECTION I

PURPOSE

1. This technical order is published for the purpose of establishing basic principles and rules for USAF property classification. USAF property listed in current USAF Supply Catalogs at variance with the provisions of this technical order will be reclassified and transferred only as directed by Hq, AMC, on an orderly program basis, and in accordance with the provisions of Sections IV and V hereof.

SECTION II

PRINCIPLES OF CLASSIFICATION

1. BASIC PRINCIPLES.

Property classification is a systematic grouping of related items by classes.

a. A property class is established to facilitate supply of functionally related items when such items are of sufficient group importance to warrant segregation from other property.

b. A property class is often divided into subclasses to facilitate the supply of closely related items.

c. An item is assigned to a property subclass after complete identification and determination as to whether it is a special or general purpose item.

d. An item will be assigned to one property subclass.

e. A special purpose item will be reclassified in the appropriate general purpose subclass when general purpose applications are determined.

Figure 4—1. Property Classification of USAF Materiel.

procurement, storage, and issue. These classes were designated by numbers running from 01 to 29. To date there have been no changes in these numbers, designating the classes, although class 30, 31, and 32 have been added. Supplies in storage or in an issue warehouse are physically segregated in each of these classes. In other words, requisition, storage, and issue of Air Force technical supply is in accordance with these thirty-two main classes.

These classes were broken down into subclasses by adding a letter of the alphabet, i.e., 01-A, 01-B, etc. The subclasses were segregated in some cases according to manufacturer and according to item grouping in others. Examples of these classes of USAF equipment and supplies are:

01—Aircraft and Maintenance Parts.

02—Aircraft Engines and Maintenance Parts.

03—Aircraft and Engine Accessories and Maintenance Parts.

05—Aircraft Instruments.

06—Fuels, Lubricants and Gases.

11—Aircraft Armament.

16—Communications Equipment.

21—Cordage, Leather and Fabrics.

The complete property classification of Air Force equipment and supplies can be found in T.O. 00-35A-1, titled "Classification of United States Air Forces Equipment and Supplies." (See Figure 4-1.)

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Likewise, each of the thousands of Technical Orders that tell how to operate and maintain equipment and how to repair and modify weaknesses and defects in equipment are numbered according to the class of the item. For example: Technical Orders on aircraft will start with the number 01; for engines the number will be 02; the number 11 will be on Technical Orders that give information on armament.

3. THE AIR FORCE STOCK NUMBERING SYSTEM

While the thirty-two main property classes and their subdivisions served very well for segregating items in storage, they did not provide identification for listing or cataloging the thousands of items of Air Corps supply. In 1929, tabulating machines for recording stock balances and consumption data were installed in all the depots. These machines had no letters and could punch only numbers on the tabulating cards. Therefore, a new system of class code numbers running from 01 to 99 was adopted, grouping items according to use or nomenclature. There is no connection between the class numbers 01 and 99 and the class symbols 01A, 01B, etc. However, it was originally intended that the code numbers would be a numerical equivalent to the class symbols of numbers and letters, and that fact makes the classification system especially confusing to the individual who is not familiar with it.

The class code provides a positive numerical identification of Air Force equipment, facilitates accurate requisitioning, procurement, storage, issue, inventory and disposition of property.

These basic class codes running from 01 to 99 may indicate:

An entire class of supply (class code 01 designating the entire class of aircraft and maintenance parts).

A subclass (class code 40 designating subclass 03-A, propellers and related parts).

A special grouping of material (class code 91 designating shop and warehouse machinery, power tools, and equipment).

Although the code number was first adopted due to the limitations of the tabulating machines, it has been especially important since 1935, when it came to be used as the first element of the stock number of every item of Air Corps property.

For each separate piece of Air Force equipment there will be a stock number assigned. A separate stock number will be assigned for each item in order that the USAF activities can accomplish positive numerical identification of USAF equipment and supplies.

In all cases a stock number consists of two elements. The first is a four-digit classification code number that is referred to as either the class code number or the classification code number. The second element is called the serial number. It will consist of a number of not more than fifteen positions.

Example of a complete stock number:

5412-266794

The first element, 5412, is the classification code number. The second element, 266794, is the serial number. The first two digits of the classification code number actually form the basic class code numbers 01 to 99.

Four-digit Classification Code Number

The first two digits of a classification code number assigned to 01 and 02 classes indicate whether the item is an aircraft part or an engine part. The third and fourth digits of a classification code number assigned to subclasses 01 and 02 indicate the manufacturer of the item. For example, the classification code 0121 indicates an item with that number assigned is an aircraft part manufactured from Martin Engineering Data (Class 01-K). Classification code 0235 indicates an item with that number assigned is an engine part manufactured from Pratt & Whitney Engineering Data (Class 02-H).

The first two digits of the classification code numbers of Classes 03-A, 03-B, 03-C, 03-D, 03-F, 03-G, 03-H, 03-I, 03-J, 03-K, 03-M, 05-A, 05-C, 05-D, 05-E, 05-F, 05-G, 11-D, 11-E, 16-D, 18, 19-C, 19-D and 32 indicate the classification of the item. The third and fourth digits of the code identify the item either to manufacturer or to a certain category of items within the class. The third and fourth digits of the code for class 32 items identify the manufacturing company. For example, the classification code 4206 indicates that an item with that number assigned is a class 03-C2 item manufactured from Breeze Engineering Data. Classification code 4305 indicates that an item with that code number is a Class 03-D item manufactured from Bendix Engineering Data. Classification code 1953 indicates that an item with that code number is a Class 19-D item falling into the "Galley Equipment and Utensils" category of items.

The classification code number for all classes except those listed above indicates the classification of the item. No information will be contained in the classification code numbers of these classes to identify the manufacturer.

Serial Number Portion of the Stock Number

The serial number for the 01 and 02 Classes and for Class 03-A, 03-B, 03-C, 03-D, 03-E, 03-F, 03-G, 03-H, 03-I, 03-J, 03-K, 03-M, 05-A, 05-C, 05-D, 05-E, 05-F, 05-G, 11-D, 11-E, 16-D, 18, 19-C, 19-D, and 32 will be the manufacturer's part number.

In cases where the manufacturer's part number exceeds fifteen positions or where no part number has been assigned, or when two or more items are carried under the same part number (except items in Class 03-E), a special assigned serial number must be used. The special assigned serial number consists of the arbitrary letters "AAF"* followed by a number of not less than six nor more than twelve digits. (*In this instance, the letters "AAF" do not represent the initials of any word or of any branch of the Armed Forces.)

For class 32 items where the manufacturer's part number exceeds fifteen positions or where no part number has been assigned, or when two or more items are carried under the same part number, a special assigned serial number must be used. The special assigned serial number will consist of the arbitrary letters "XM" followed by a number of not less than five nor more than thirteen digits.

The serial number portion of the stock number for those items carried in class 15 and subclass 17-D will be as follows:

Class 15 Items. The serial number portion will be the Technical Order number, the manufacturer's service bulletin number, or the manufacturer's part number assigned to the kit.

Subclass 17-D Items. The serial number portion will be the Technical Order number that has been assigned to the kit in accordance with T.O. 00-30-1.

The serial number portion of the stock number for the balance of the classes will be the same as those shown in current supply catalogs and supply catalog addenda.

For additional information on the Air Force stock number system refer to: T.O. 00-35A-8, titled "Air Force Stock Number System."

As was mentioned previously, the serial part of the stock number in most cases will be the manufacturer's part number. This is a number assigned by the manufacturer and corresponds to the number used in his basic drawing. It also corresponds to the nomenclature of the item being manufactured. Example: A382-054 is the serial element of a stock number for a carburetor-restriction diaphragm manufactured by Holley Carburetor Company. The number A382 is the Holley Company part number. The 054 is a suffix to the part number. This suffix is to show the distinguishing feature of an item by a symbol or number representing quantity of measurement—the size of a hole, for example, or capacity of a jet in a carburetor fuel injector, or the water column reading in an automatic mixture control.

In order to establish basic principles and rules for obtaining and using part numbers and nomenclature, the Air Force has published T.O. 00-35A-6, titled "Administrative—Part Numbers and Nomenclature." From this Technical Order one can learn the part number filing system that is used on all property records and paper work incident to procurement, requisitioning, shipment, storage, and issue of Air Forces property.

Part numbers may contain letters, numbers, diagonals, period, dashes, and spaces. Since this is so it has been necessary that a filing system be devised in order to file them in a logical manner.

Part Number Filing System

Classes of property indicated in T.O. 00-35A-8, are filed and controlled by a part number. Air Force activities will arrange stock record cards, bin locator cards, and report stock balance changes in these classes in accordance with the part number filing system described below.

Principle. Part number arrangement shall begin on the extreme left-hand position and continue from left to right, one position at a time, until the part number arrangement is determined.

First Position Arrangement. The order of precedence in beginning the part number arrangement on the extreme left-hand (first) position of the part number shall be as follows:

Letters A through Z
Numerals 0 through 9
Note: Letter "O" not used.

Second and Succeeding Position Arrangement. The order of precedence in continuing the part number arrangement on the second and succeeding positions of the part number from left to right shall be as follows:

Space (Blank Column)

Diagonal (Slant) (/) (Signal Corps Numbers Only, Except Class 16-F)

Point (Period) (.) (Signal Corps Numbers Only, Except Class 16-F)

Dash (—)

Letters A through Z (omitting "O")

Numerals 0 through 9

Spaces, Diagonals, Points and Dashes. Spaces, diagonals, points, and dashes shall not appear in the extreme left-hand position of the part number; however, they are found in the second and succeeding positions of the part number and shall take precedence over letters and numerals as indicated in the preceding instructions.

4. USAF SUPPLY CATALOG

The Air Force stores and issues 650,000 items of Air Force technical supply. Up to this point, you have learned how all these items were classified, the stock number system, and the part number filing system. The next part of this section will deal with the publications that list all the separate items. These publications are called **USAF Supply Catalogs.** They were formerly called Stock Lists.

All supply catalog publications are readily identified by the symbol "S" employed as a prefix to the assigned publication number. The assigned publication number is the property class symbol. There is published an individual publication for each AF property class and subclass. For example: The class symbol for bombing equipment, accessories and related parts is 11-A. The supply catalog publication that lists all the items in this property class would be identified as "S-11-A."

AF supply catalogs contain part numbers, standardized nomenclature, regulated item information status and expendability codes, units of issue, unit costs, and stock numbers of AF property in stock, or in process of procurement, and information on items for which disposal action has been directed.

Application, general supply action or action reference phrases and authorities for local manufacture or local purchase and such other supply information as may from time to time be necessary are included where applicable. Illustrations and identifying information are included in supply catalogs (stock lists) for certain classes.

AF supply catalogs are the official item identification lists of AF equipment, supplies, and spare parts. These catalogs are published separately by property class.

Addenda are issued in the supply catalog publication system for the same purpose as supplements, except that addenda are issued as integral parts of the basic publication which they supplement and bear the same number as the basic publication. Addenda are widely used as a means of revising supply catalogs to include numerous items and changes which cannot be economically incorporated in their proper order in the basic lists until the time of reissue.

Identification. As addenda are components of publications, they are issued with revised title pages for the affected publications, each bearing a revised publication date and a "revision strip." Inclusion of an addendum in a publication is reflected on the "A" page in a manner similar to that employed for revision pages.

Supply Catalog (Stock List) Change Notices

AF supply catalog (stock list) change notices are official supplementary publications issued to disseminate important changes and additions in advance of revisions or reissues of AF supply catalog (stock list) publications. These change notices are cumulative; they reflect in each issue the information contained in the previous notices, except that certain one-time announcements and items incorporated in subsequently distributed revisions, addenda, or reissues of supply catalog (stock list) publications are omitted. Each newly issued change notice, therefore, replaces the preceding publication of like category. For reference purposes, supply catalog (stock list) change notices are to be used in conjunction with basic supply catalog (stock list) publications.

Supply catalog (stock list) change notices are indicated by a dash number added to the active related supply catalog, as, for example, "S-04A-1," "S-04B-2," etc. Part number indexes are numbered "S-00-1."

To understand the information that is included in this publication, it will be necessary to learn the codes that are used in the columns as well as the purpose of the columns.

Arrangement

Part Number (if any) is shown under that heading.

Name. The complete nomenclature consists of the description in boldface capital letters, or all the wording under the heading "name" up to the first three dashes. The information following the first three dashes does not constitute part of the nomenclature and should not be used on reports and forms.

Issue Control. Regulated items are indicated by the symbols "HQ" and "SD" and are defined as follows:

HQ—Controlled by Hq., AMC.
SD—Controlled by Specialized Depot.

(For definitions of "Regulated" see AF Materiel & Services Directive 67-40.)

Status. The following codes designate the status of articles as to procurement, storage and issue:

X—Experimental
ST—Service Test
LP—Limited Procurement
S—Standard
SS—Substitute Standard
LS—Limited Standard
(For definitions of above see AR 850-25.)

The following codes designate the status of articles as to expendability:

NX—Nonexpendable
R—Recoverable
NR—Nonrecoverable (Expendable)
XC—Nonrecoverable, Subject to Pilferage
(For definitions of above see AFR 65-38.)

Unit of Issue. Under this heading, it is indicated whether items are issued in quantities of each, by the pair, by the barrel, etc.

Unit Cost. The cost indicated under this heading is expressed in dollars and decimals of a dollar. For example, an item having a unit cost of .105 is ten cents and five mills.

Stock Number. This column is divided into two elements; both make up the stock number. Under "class" is the classification code number. Under "serial" is the assigned number. If no numbers appear under the serial portion then the part number will be used along with the class code number, thus completing the stock number.

Change. New items and changes are indicated by a numeral in the "change" column, and each numeral indicates the addendum wherein the addition or change appeared first. Thus, all items showing the numeral "1" will be those listed in the first addendum.

Margin. Symbols ACT or REF will appear in the extreme right-hand margin of each page. These mean:

ACT—Item of active status, or change on active item, or reactivated item.

REF—Action directives such as "Change to," "Consolidate with," etc.

The arrangement as explained above is not consistent in all supply catalog publications. The same information can be found but the listing of items and information will be in different arrangement. Further discussion of the listing arrangements will be made in this section.

Before the supply catalog publications may be used, it will be necessary to identify the item as to name, part number, and/or the manufacturer of the item to be ordered. This is necessary because the supply catalog publications will have the items listed either and alphabetically, numerically, and in some cases, numerically according to the manufacturer.

5. PROCEDURE FOR USING USAF SUPPLY CATALOG

Identification

To obtain complete identification for individual items of property the following listed sources will be used, in the order named, if applicable:

Name plates, container labels, or tags.

AN and AF Drawings.

Aircraft, Engine, and Accessories Manufacturers' Drawings.

Parts Catalogs in the Technical Order File.

Federal, JAN, AN, AF, and U. S. Army Specifications.

AF Contracts and Maintenance Parts Breakdowns.

Manufacturers' (Commercial) Catalogs.

Handbooks of Assembly and Maintenance Instructions (Technical Orders).

Shipping Tickets or Packing Lists.

Note: The approved sources for obtaining part numbers and nomenclature used on all AF property records and paper work are AF supply catalog publications.

In no case will the classification, other than that established in the appropriate USAF supply catalog or addendum, be considered authentic.

The above listed sources aid in finding information necessary to use the supply catalog publications.

After identifying the item, it is then necessary to determine the USAF property class that the item is stored under.

Classification

Technical Order 00-35A-1 titled "Classification of United States Air Forces Equipment and Supplies" is the publication to use. Another publication that can be used is the "USAF Numerical Part Number Index for Property Classification" which will be used to facilitate determination as to the proper USAF supply catalog in which part numbered items are published.

Procuring

The next step is to obtain the supply catalog that the item is listed in. The publication will be numbered with an "S" before the class symbol. For example: A bombsight is stored in the USAF property class "Bombing Equipment, Accessories and Related Parts." The class symbol for this property class is 11-A. The supply catalog publication for this property class will be numbered S-11-A.

Whenever it is necessary to find out if the publication is the latest issue, T.O. 00-1-1 should be referred to. All supply catalog publications are indexed in this Technical Order.

The next step is to locate the item in the supply catalog publications.

Location

In these publications, the items will be listed either and or alphabetically, numerically, and in some cases, numerically according to the manufacturer.

6. USAF SUPPLY CATALOG SECTIONS

The following are figures and explanations of the different types of supply catalog arrangements.

Note: Each publication will have a table of contents on the front page. From this can be determined the arrangement therein. There is a preface in every publication explaining the supply catalog for that particular class.

It will be definitely advantageous and profitable in terms of a job better done to read very

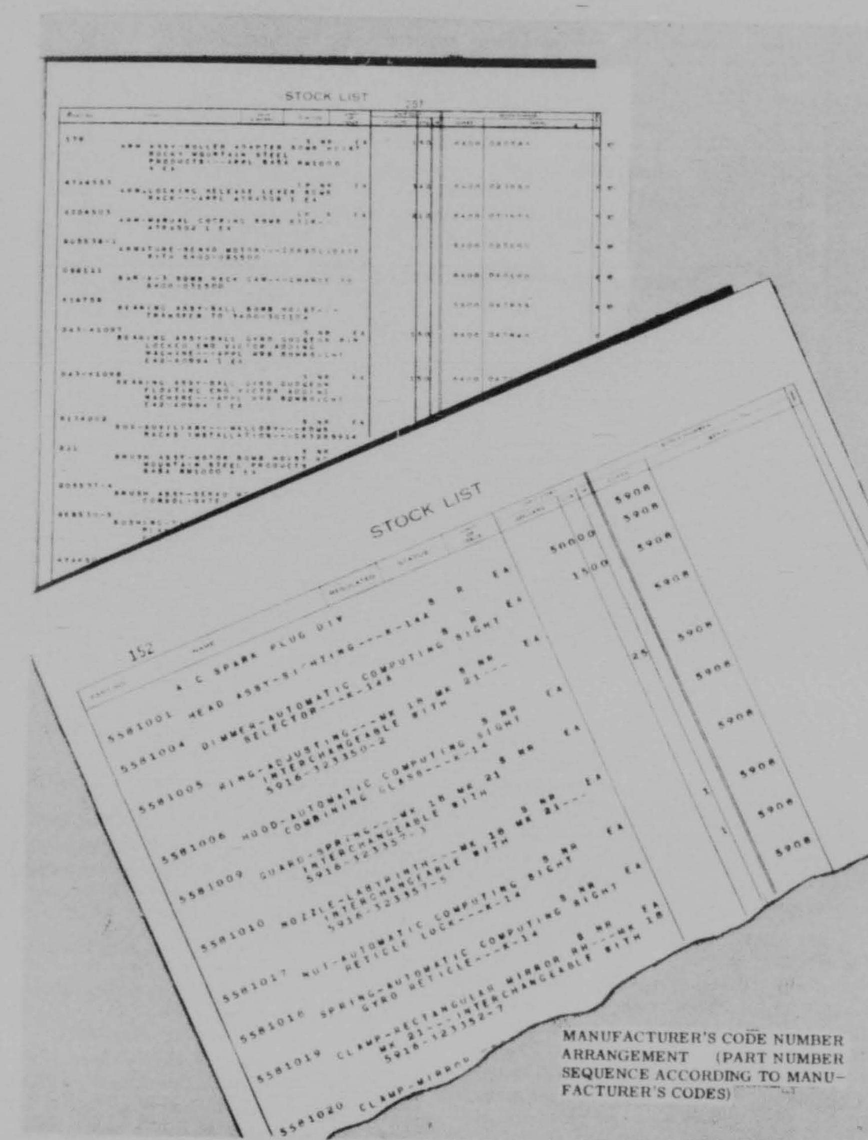

Figure 4-2. Alphabetical Sequence in Stock Number Sequence.

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PART NO.	NAME	STOCK NUMBER CLASS	STOCK NUMBER SERIAL	PART NO.	NAME	STOCK NUMBER CLASS	STOCK NUMBER SERIAL	CHANGE
3-20800-1		6400	849018	32A043		6400	577325	
3-20801		6400	856215	32A044-2		6400	856965	
3-20801-1		6400	849020	32A044-50		6400	376885	
3-21119		6400	100125	32A044-51		6400	376887	
3-21119-1		6400	100130	32A044-51R		6400	376490	
3-6738		6400	075000	32A044-52		6400	376889	
3-6864-119		6400	235330	32A044-53		6400	376891	
3-7819-4		6400	058200	32A044-6		6400	045205	

Figure 4–3. Part Number Index.

carefully the important explanations and directions on the pages preceding the supply catalog publications. A thorough understanding and knowledge of these facts will result in an easier, faster, and more accurate performance of various tasks in connection with the publication.

In most supply catalogs there will be three sections:

The basic stock list
Part number Index
Addendum.

Basic Stock List

The basic stock list will be generally one of two types. The first type of arrangement will have the items arranged alphabetically, regardless of the manufacturers of the item. In this type of arrangement, the stock numbers are arranged in numerical sequence; although they do not fall in strict sequence they are in an increasing numerical arrangement.

In the second type of item, arrangement of the articles is first segregated as to the manufacturer of the item. Then the articles are arranged in part number sequence under the class code of the individual manufacturer. (For class codes see T.O. 00-35A-8.) The part numbers will be according to the part number filing system that was explained previously. In this type of arrangement, the serial element of the stock number will be the part number. Figure 4-2 shows the two types of the basic stock list.

Part Number Index

In this section, the part numbers will be arranged according to the part number filing system only. They are cross-referenced to the stock number or the manufacturer's code number. No other information is contained in this section. For other information, it will be necessary to refer back to the basic stock list section. To clarify the above, the following two examples are cited:

Example 1: Figure 4-3 is from the supply catalog whose first section has the items arranged alphabetically, and with the stock numbers in numerical sequence.

This part number index will be used if the nomenclature is unknown and cannot be found in the basic stock list.

After locating the part number, it is cross-referenced to the stock number. Now, knowing the stock number, it is possible to find the stock number in the basic stock list section because the basic stock list section is arranged alphabetically and in stock number sequence. Upon locating the stock number, all other information can be obtained.

Example 2: Figure 4-4 is from the supply catalog whose first section has the items arranged according to the manufacturer's code number and in part number sequence.

In this index, the part number is cross-referenced to the manufacturer's code number only. It then will be necessary to turn to the basic stock list and locate the code number.

After the code number has been found, the part number may be found.

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PART NO.	STOCK NUMBER CLASS	STOCK NUMBER SERIAL	PART NO.	NAME	STOCK NUMBER CLASS	STOCK NUMBER SERIAL	
9000800G2	5901		9030451G1		5901		
9000801P1	5901		9030452G1		5901		
9000879P1	5901		9030517P1		5901		
9000881P1	5901		9030518P1		5901		
9000883G1	5901		9030604P1		5901		
9000890P1	5901		9030657G1		5901		
9000942G1	5901		9030567P1		5901		
9000943P16	5901		9030686G1		5901		
9000996G1	5901		9030690P1		5901		
9000996G2	5901		9030642P1		5901		
9005009G1	5901		9030692P2		5901		

Figure 4–4. Part Numbers–Class, etc.

Note: The part number will be listed according to the part number filing system. The serial element of the stock number will be the part number.

Addendum. Contains item information that has been published after the basic stock list.

The current status of an item is the one indicated in the latest catalog publication, be it a USAF supply catalog, addendum or revisions thereto, or change notice. Upon using these publications, one should always consult the change notice first, then the addendum and basic catalog if necessary. For additional information regarding each type of publication, one should refer to the corresponding preface.

All the above publications referred to are used whenever information is desired on equipment and supplies procured and issued by the United States Air Force.

Whenever it is necessary to find information on the equipment issued and procured by the following technical services, it will be necessary to use the Department of the Army supply catalog and other publications.

Ordnance Department
Signal Corps
Quartermaster Corps
Corps of Engineers
Transportation Corps
Chemical Corps
Medical Department

SECTION III—DEPARTMENT OF THE ARMY SUPPLY

1. DEPARTMENT OF THE ARMY SUPPLY CATALOG

The Department of the Army supply catalog is made up of a separate series for each technical service. The series for each service is identified by a letter symbol. This letter symbol will identify the pamphlets of the technical services.

Letter Symbol	Catalog Series
ORD	**Ordnance**
CML	**Chemical**
ENG	**Engineer**
MED	**Medical**
QM	**Quartermaster**
SIG	**Signal**
TC	**Transportation**

Each series is issued to cover the material normally handled by each technical service.

Each series is issued in sections which often consist of many individual pamphlets. These sections will vary in their content and numbering according to the technical service that prepares them. In general the contents of these sections are as follows:

Section 1: Introduction and Index. This is a guide to all sections of the catalog system of the originating service, with explanation of its content and use, requisitioning procedures, and other necessary general information; it contains the identifying number, and alphabetic listing of titles of each publication. (There is no Section 2, since 1 and 2 have been combined in Section 1.)

Section 3: Major Item Lists. Contains a list of major items, major combinations, and such other items whose basis of issue is generally established by T O&E's, etc.

Section 4: Allowance of Expendable Supplies.

Section 5: List of All Items. This section may be published in several series. The information in each series may be pamphlets that list the standard hardware, bulk materiel, and miscellaneous items; or part number indices, and pricing guides.

Section 6: Sets, Kits, and Outfits. This section consists of pamphlets listing tool and gage sets and their component parts.

Section 7: Organizational Maintenance Allowances. Section 7 pamphlets are published only for those items of materiel that require issuance of equipment and or spare parts to using troops for the operation of the major item, and the performance of organizational maintenance. These pamphlets list the authorized allowances of spare parts and equipment that are issued with the major item.

Section 8: Field and Base Maintenance Spare Parts and Equipment. These pamphlets are published only for those items of materiel that require spare parts for field and or base maintenance. These pamphlets contain stock guides of extra major items, spare parts and equipment estimated to be required by field and base maintenance and supply operations.

Section 9: List of all Parts or List of all Service Parts. This section consists of pamphlets listing alphabetically each part and assembly comprising a major item. The assemblies and subassemblies are generally illustrated. It is used for identification purposes and not for requisitioning purposes.

Section 10: Section 10 and all other sections will be used as the technical service desires.

The above numbered sections will be identified by the letter symbol of the technical service. For example: Section 1 is the introduction and index. If the pamphlet is published by the Ordnance Department it will be printed as ORD 1. If the pamphlet is to be the introduction and index of Chemical Warfare Service, it will be recognized by the "CML 1."

Since it will be impossible to discuss fully all the series that comprise the Department of the Army supply catalog, we will explain the Ordnance pamphlets. All the series will be similar in nature, so understanding one will aid in understanding all others.

Note: Before attempting to use any of the technical service pamphlets one should read carefully Section 1 of each technical service catalog.

The Air Force armament officer will have to know how to use the pamphlets of the Ordnance supply catalog since much of the equipment he will use is procured and issued by the Ordnance Department.

2. ORDNANCE PROPERTY CLASSIFICATION

The large number and variety of items designed, procured, stored, issued, and maintained by the Ordnance Department necessitates the segregation of these items into nineteen major classifications. Each classification is identified by a letter (Group A, Group B, etc.). This letter is called the classification letter symbol.

Indicated below are the types of materiel assigned to each of these lettered groups.

Group A: Automatic weapons

Group B: Small arms, hand arms

Group C: Light and medium field artillery

Group D: Heavy field artillery

Group E: Railway artillery

Group F: Instruments used for range finding and for control and observation of fire.

Group G: Armored, half-track, and scout cars, motor carriages.

Group H: Standard hardware

Group J: Common tools, machines, and tool appurtenances.

Group K: Materials required in the cleaning and preservation of ordnance general supplies and ammunition.

Group L: Targets and target material.

Group M: Electrical apparatus units and parts.

Group N: Units of equipment, and material not otherwise classified such as, maneuvering material, power plants, reconditioning outfits, ammunition surveillance equipment.

Group P: Ammunition for medium and major caliber seacoast artillery.

Group R: Ammunition for minor and medium caliber field artillery.

Group S: Bombs, mines and torpedoes for aircraft.

Group T: Small arms ammunition.

Group Z: Captured foreign materiel.

Group OGS: Obsolete general supplies.

Within each lettered group, each major item or category of tools or supplies, is assigned to a numbered subgroup which, when combined with the major classification letter symbol, serves as a classification code. Subgroup numbers are assigned consecutively beginning with "1" upon accession of a new type item into the system. Thus, the pistol, automatic, cal. .45, M1911, being a hand arm, falls into letter group "B." When this materiel was originally classified as standard, the next subgroup number in sequence was "6." This number combined with the letter of the major classification forms the SNL classification code "B-6."

Any supply pamphlet issued by the Ordnance Department on the pistol, automatic, cal. .45, M1911 will be identified by the classification code "SNL B-6."

From the explanation above, it then follows that every major item procured by the Ordnance Department will have its own SNL classification code. Therefore the SNL classification code will designate the piece of equipment.

The numbered sections (Section 1 and 2 introduction and index, etc.) will designate the kind of information that will be contained within the pamphlet. For example, Section 7 "Organizational Maintenance Allowances" lists the authorized allowances of spare parts and equipment that are issued with the major item. When this numbered section is combined with the SNL classification code, it will be a listing of spare parts and equipment for a specific item.

A pamphlet titled "ORD 7 SNL B-6" will be the organization maintenance allowances (Section 7) authorized an organization for the pistol, automatic cal. .45, M1911 (SNL B-6).

A pamphlet that lists the authorized spare parts and equipment for the above mentioned weapon for field and base maintenance would be identified by "ORD 8 SNL B-6" titled "Field and Base Maintenance Spare Parts and Equipment" for the pistol, automatic, cal. .45, M1911."

A "List of all Parts" for the pistol, automatic, cal. .45, M1911 will be identified by "ORD 9 SNL B-6."

A separate pamphlet is published for each group in order that an individual may find what items are included therein. The pamphlet for Group A will be published as "ORD 3 SNL A-1" titled "Major Item Lists for Group A."

For Group B the pamphlet will be published as "ORD SNL B-1."

The pamphlets in Section 3 (ORD 3) will list all the items that have been segregated into the various lettered groups.

ORD 6 "Sets, Kits, and Outfits" itemizes the individual items that comprise sets, kits, and outfits that are authorized by T O&E's, T A's, etc. For example: T O&E's state that an organization is authorized a "Tool Set, Unit Equipment, Second Echelon Set No. 1";

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the pertinent catalog pamphlet. ORD 6 SNL G-27, section 2, enumerates the components of the set in detail.

The other sections that are used by the Ordnance Department are:

ORD 10—Tool, Load and Supply Guides. This section is composed of separate pamphlets, each of which lists the tools and supplies required by a particular ordnance unit for its assigned maintenance and or supply mission. Example: ORD 10 SNL N-257, Tools and Supplies for Ordnance Maintenance Company, Air Force. ORD 10 SNL N-20, Tools and Supplies for Field Maintenance Post, Camp, and Station Ordnance Shops.

ORD 11—Ammunition. This section consists of pamphlets listing ammunition, demolition materiels, bombs, mines, etc. Example: ORD 11 SNL S-1, Bombs, Aircraft, All Types.

ORD 12—Obsolete General Supplies. This section is composed of pamphlets listing major items that have been classified obsolete by official action. Example: ORD 12 OGS-1, Obsolete Major Items.

ORD 13—Items Common to two or more Major Items. The pamphlets of this section list parts and equipment that are common to two or more items of ordnance materiel. One pamphlet is published for each lettered group, listing parts and equipment common to more than one major item within the group. Example: ORD 13 SNL A-19, Items Common to Two or More Group A Materiel.

ORD 13 SNL M-5—Items Common to Two or More Groups. This pamphlet lists parts and equipment that are common to major items that are not classified in the same lettered group.

ORD 14—Interchangeability List. This section lists major assemblies used in automotive materiel. By the use of charts, shows application and interchangeability of these major assemblies.

ORD 15—Cross Reference Lists. These pamphlets provide a cross reference of ordnance and manufacturers' part and drawing numbers to the assigned stock numbers.

ORD 16—Captured Foreign Materiel. This section lists the items of captured enemy materiel which may be used for training or for donation.

In ORD 1 Introduction and Index all pamphlets that have been distributed are listed both alphabetic and numerical. Any published pamphlet can be found if the procedure below is followed. For instance, to determine which publication lists the spare parts and equipment for the pistol, automatic, cal. .45, M1911 for a squadron,

Obtain: ORD 1—Introduction and Index.

Locate: Locate the nomenclature of the materiel on which a pamphlet is desired in the alphabetical list and obtain the pamphlet (SNL) number.

Locate: Locate the pamphlet number in the numerical list. The numerical list will have the SNL number listed numerically according to the Group. (Group A, Group B, etc.) The SNL number is followed by the catalog designation (ORD 7, ORD 8, ORD 9). ORD 7 is titled "Organizational Maintenance Allowances." Since this section lists the authorized allowances that are issued with the major item, this will be the one used for a squadron. The pamphlet title is then ORD 7 SNL B-6.

Each ORD 7 pamphlet contains:

An alphabetical list of the spare parts by item name giving the quantities (stock levels) which are maintained by using organizations for performing organizational maintenance.

An alphabetical list of the tools, equipment, sighting equipment, cleaning and preserving materiels, and instructional aids which are authorized units equipped with the major item.

SECTION IV—SUPPLY PUBLICATION CHANNELS AND AUTHORIZATION

1. SUPPLY PUBLICATIONS

The publications discussed up to this point are the official Department of the Army and the Department of the Air Force publications that will be used only for item identification. These supply catalogs do not explain or establish the system used for stock control; nor do they explain the standardized procedures for the requisition, purchase, receipt, storage, issue, shipment, and accounting for supplies.

The Air Force has published AF Manual 67-1, "USAF Supply Manual" which establishes a uniform system of stock control throughout the Air Force. This volume prescribes standardized procedures for the requisition, purchase, receipt, storage, stock control, issue, shipment, and identification of and accounting for supplies by Air Force organizations.

Other publications that disseminate instructions and information on supply matters such as requisitions and issue, warehouse and depot administration and procedure, safety information, storage, packing, marking, and shipping are the "Air Force Materiel and Service Directives." These publications are issued by the Air Materiel Command.

The Department of the Army has published many field and technical manuals that established a system of stock control for the technical services. To supplement these publications "Supply" bulletins have also been published by the Army. All the Department of the Army publications are listed and indexed in FM 21-6.

2. DISTRIBUTION

We have not discussed the physical setup of the depots that provide a system of distribution. The purpose of distribution is to provide a complete stock of tools and equipment and to maintain in stock predetermined quantities of specified items of frequent issue conveniently located and reserved for issue to a maintenance shop, repair activity, or squadron for use in performing its mission.

Distribution includes the procedures and operations by which supplies are moved—from the time an article is first accepted from a manufacturer or supplier until it is issued to the using unit. Distribution agencies direct and supervise this flow of supplies in accordance with approved policies or directives. Storage or transportation agencies accomplish the physical distribution operation.

In following the basic principles of distribution, one must:

Limit issues to authorized allowances. The flow of supplies in a distribution system is based upon specific estimates of requirements as reflected in authorization tables and upon anticipated special needs. (If excess quantities are issued without authority they will not be reflected in supply planning and disruption of the supply plan will result.)

Limit stocks to minimum requirements. Large stocks which do not move increase the initial cost and also increase storage, maintenance, and handling costs. Aircraft, weapons, and ammunition which cannot be procured readily in time of an emergency may be held in reserve. (As a rule, lower echelons should have balanced stocks sufficient for their needs but not so great as to impose a storage burden or to lessen mobility.)

Decentralize operations. Military installations must be able to call directly on depots without having their requisitions previously edited and delay imposed by intermediate agencies. (Decentralization is essential not only to speed up supply operations but to place responsibility in the hands of the agency charged with the distribution of supplies.)

Standardize procedures. Standard procedures are necessary to the orderly handling of our vast complex of supplies in the distribution system; troops must be able to follow standard supply procedures wherever they are stationed.

Serve the combat forces. Supplies become effective when they are issued to combat forces; the objective must be to have adequate quantities located in close proximity to

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the combat troops so that the supplies may be issued promptly as needed.

The distribution of Air Force supplies is accomplished through Air Force supply channels. The Air Materiel Command is the Air Force agency charged with the procurement, storage, and distribution of Air Force supplies. Distribution is made through Air Materiel area depots, Air Force specialized depots, and Air intransit depots. Headquarters, Air Materiel Command, prescribes the levels of supplies established within the Air Force supply system. That headquarters is also charged with the responsibility of establishing supply procedures of the Air Force.

Common items of supply are distributed to the Air Force through Army supply channels which include general distribution depots, technical service or branch depots, reserve depots, and the various types of theater of operation depots. Levels of supply within the zone of the interior and those authorized for the several theaters are prescribed by the Department of the Army. Regulations governing supply procedures and techniques are prepared by the technical services and are approved and issued by the Department of the Army.

3. AUTHORIZATION TABLES

Authorization tables form the basis of issue of all supplies, both common and Air Force technical supplies, required by the Air Force in equipping an organization, an Air Force base, or an individual airman. Those authorization tables which will be considered in this section will be limited to the three most common in Air Force operations and which form the basis of initial supply to an organization, an Air Force base, or an individual. They are: (1) Tables of Organization and Equipment (T O&E) (2) Table of Allowance 20-1 and (3) Table of Allowance 21.

Tables of Organization and Equipment

Tables of Organization and Equipment which will be referred to hereafter as T O&E, prescribe the organic structure and equipment of military units, the organization, strength, and functions of which are not subject to frequent change.

At the time a squadron is activated, the activation orders specify the T O&E under which the squadron is to be organized and equipped. This T O&E then becomes the authority for issue to the squadron of all the items of equipment it lists. The equipment listed in the table is all essential equipment and it does not include any items that might be called "luxury" items. Desks listed are field desks; chairs are folding chairs. While the squadron is in garrison, the commander will probably draw from base supply, on memorandum receipt, articles such as desks, chairs, mess equipment, etc. This equipment which the squadron has borrowed from the base is known as post, camp, and station property since it is authorized for the base by a Table of Allowances. Before the squadron moves, it must turn in all this post, camp, and station property.

The Chief of Staff, United States Air Force, has responsibility for the preparation of T O&E's for units assigned to the Air Force. Likewise, the Chief of Staff, United States Army is responsible for the preparation of T O&E's for the Army.

Commanders of any Air Force unit may recommend changes on any of these tables to the Air Materiel Command.

T O&E's fall into one of four categories: normal or standard, special, tentative, and restricted. Each of these tables may be identified by the serial designation in the upper right-hand corner. Normal tables are designated by numbers only, while special, tentative, and restricted tables have letters S, T, and R respectively as suffixes after the number. For example: 1-67 is a normal table, and 1-167R is a restricted table.

Standard Tables. Standard tables are tables of normal and general application and are the ones under which most units will be organized. They have been formulated through tests and experience, have proven satisfactory, and have been approved by the Department of the Air Force or Army.

Special Tables. Special tables are used by a unit which has a special mission to perform.

If the special mission is such as to require a drastic change in both organization and equipment, the unit would operate under a special table. In many cases, however, the special mission would only require extra equipment and not changes in personnel. If these conditions exist, the unit may perform the mission while organized under a standard table by using a special list of equipment (SLOE) to augment its T O&E equipment. An example would be a group operating in the Arctic.

Tentative Tables. When a new-type plane comes out, no one knows exactly what is needed in men and materials to service, fly, and maintain it. Tests are then run on both organization and equipment to determine just what is needed to allow a unit to operate satisfactorily with the new plane. Changes are made as needed, and upon completion of the tests, standard tables are prepared.

Restricted Tables. Restricted tables are known as reduced tables, new tables, or revised tables. They are used by units undergoing processing or reorganization. An examination of an "R" table shows that a unit loses many of its maintenance men and a great deal of its equipment.

Sections. Section I of the tables prescribes the authorized number, grades and qualifications of personnel. Section II of the tables prescribes the authorized allowances of equipment for units organized with the strength as provided in Section I of the table except:

Equipment required for temporary use and for special purpose.

Items of clothing and equipment included in TA 21.

Component parts, spare parts, accessories, and expendable items which are listed in the Department of the Army and Air Force supply catalogs, AF Technical Orders of the 00-30 series, and circulars ~~and~~ bulletins of the various technical services.

Tables of Allowance 20-1. Tables of Allowance 20-1 authorize those items of equipment which are normally required for housing, administration, supply, and servicing facilities at Air Force installations. This includes equipment for that training which is common to, and conducted by, all Air Force organizations and activities.

The form and arrangement of this table conforms as closely as possible as that listed in Section II of the T O&E. Equipment is grouped by technical services and alphabetically within each group and is that normally required to perform the mission of the Air Force installation. Since the allotment of personnel varies for each base, the Tables of Allowances are published with much of the equipment distributed according to the number of men or planes.

Table of Allowance 21 prescribes the allowances for clothing and personal equipment of individuals regardless of where they are serving.

Part I of TA 21 contains general information pertaining to the table; it defines the boundaries of the climatic areas including the arctic, tropics and areas within the United States to which the table refers. Part II lists in detail the clothing and individual equipment authorized to be issued to officers and enlisted men and women within the United States and various theaters of operations. Part III lists the specialized clothing and equipment by organization, and for certain combat operations depending upon the type of terrain or areas in which the operation is being conducted. Part IV contains individual equipment and organizational equipment not otherwise authorized.

SECTION V—DEPOTS

1. USAF DEPOTS

To serve all air bases, Air Force troops, aircraft, and related equipment throughout the United States, there has been created an agency in USAF Hqs. that is responsible for planning and programming the logistics activities of the Air Force. This agency is the Office of the Deputy Chief of Air Staff, Materiel.

This office is guided by three directives. One is the general directive from the Joint Chiefs of Staff to the U. S. Air Force. The second is the specific directive from the Chief of Staff, U. S. Air Force. The third is the directive from the Secretary of Air, especially relative to matters of procurement and industrial planning.

The Deputy Chief of Staff, Materiel, must translate these directives into logistics requirements and outline to the operating agencies what their work must be. The principal operating agency for the Air Force in the field of logistics is the **Air Materiel Command.** The Deputy Chief of Staff, Materiel, is delegated the staff function while the Air Materiel Command has command responsibilities.

One of the primary missions of the Air Materiel Command is to supply and maintain the materiel of the Air Force. In order to serve all the various Air Force organizations, the Air Materiel Command has divided the United States into seven areas. These are called air materiel areas. Each area has an area headquarters. The commander of this headquarters is also the area commander and has command jurisdiction over all AMC activities physically located within the area. He also is charged with the responsibility of logistically supporting all Air Force troops, bases, aircraft, and any other Air Force installation physically located within the area. Each area has an Air Force depot, aircraft storage depots, and in some areas are located specialized depots.

The Air Force depot is also called air materiel area depot. These air materiel area depots receive supplies from the factories. The movement of these supplies is controlled by Hqs., Air Materiel Command. The issue of supplies from the air materiel area depots to Air Force bases depends upon authorized allowances.

The specialized depots generally store and issue supplies that are of one property class or subclass. Regulated items may also be stored and issued from these depots.

Intransit depots do not store or issue supplies but facilitate the loading and unloading of cargo carriers and the segregation, regulation, and storage of supplies.

The types of AF depots found in a theater of operations are:

Base air depots.
Air depots.
Intransit depots.

In this depot system, technical service functions are handled in the appropriate sections of the above listed AF depots.

The Base Air Depot. Within the theater, the base air depot is a large fixed installation normally located in the vicinity of a port. It is designed primarily to handle bulk quantities of supplies and specialized activities not required for the immediate, close support of combat elements. Within the vicinity of the base air depot may be located facilities for aircraft assembly, engine overhaul, aircraft modification, etc. These additional activities will very often be part of the base air depot. The base air depot receives, stores, and issues all AF technical supplies. It includes facilities necessary for maintaining in serviceable condition all of the equipment it uses as well as the equipment and supplies which it handles.

The Air Depot. Within the theater, the air depot includes the administration and facilities necessary for the storage, distribution, maintenance, salvage, and reclamation of supplies and equipment. They are normally in direct support of the combat wings.

Intransit Depots. These installations are normally attached to either a theater air materiel command, air materiel area, base air depot, or air depot and facilitate the loading and unloading of cargo carriers and the segregation, regulation, and storage of supplies. They further serve in assuring that materiel being shipped to AF organizations reaches its ultimate destination. Intransit depots have no maintenance functions. They issue no supplies. They are expediting facilities.

All activities which are peculiar to the operation of the AF in the theater are the responsibility of the theater air commander. There will be established in each theater, one theater air materiel command to which the theater air commander delegates his responsibility for the logistical support of all theater air activities. If necessary, due to scope of the operations, and or geographical conditions,

there may also be established within the theater air materiel command one or more air materiel areas. These will be charged with the responsibility within their assigned geographical areas for depot level of supply maintenance, reclamation, salvage, and the technical supervision over the organizational and field level.

Base air depots are normally under direct control of the theater air materiel command. They serve, but do not command, the air depots of the theater.

There may be several air depots in a theater. If air materiel areas are established, control of the air depots is normally delegated to them. Intransit depots may function directly under the theater air materiel command, or may be attached to an air materiel area, base air depot, or air depot.

The organization of the base air depot, and the air depot, as to types of squadrons and personnel, will vary according to the mission assigned to it and the amount of work to be accomplished.

There are many T O&E organizations that are available for assignment to these depots. A few examples:

Hq. and Base Service Squadron
T O&E 1-562R
Air Repair Squadron
T O&E 1-567R
Air Supply Squadron
T O&E 1-568R
Air Vehicle Repair Squadron
T O&E 1-569R
Air Ammunition Squadron
T O&E 1-564R
Motor Transport Squadron
T O&E 1-998R

The latest trend is to have the air depot handle all supplies, both common and AF technical supplies. The personnel and equipment are provided through the T O&E's for this assignment.

This system is an advantage to the combat wings as they will be dealing with only one depot for all supplies.

The air depot goes to the proper technical service depot to get common supplies; it does not normally get them from the base air depot.

The base air depot will handle only Air Force technical supplies.

2. ARMY DEPOTS

Depots form the backbone of the Department of the Army supply system; they are the means by which flexibility in supply operations can be assured.

At present the Department of the Army operates three types of depots, namely:

The General Distribution Depot.
The Technical Service Depot.
The Reserve Depot.

It is these departments that the Air Force is dependent upon for the distribution of all common supply items used within the Air Force.

The general distribution depot is composed of supply sections corresponding to the various technical supply services of the Department of the Army. For example, each depot has a chemical section, an engineer section, a medical section, ordnance section, etc., whose responsibility it is to procure, store, and issue all classes of supply for which each is responsible.

There are five general distribution depots within the continental limits of the U. S. They are located at Schenectady, N. Y.; Atlanta, Ga.; Columbus, Ohio; San Antonio, Texas; and Ogden, Utah. Each depot is charged with the distribution of Department of the Army supplies to all military organizations, both Army and Air Force, and civilian components of the armed forces within designated assigned geographical areas. In addition, the general distribution depot supplies the various ports of embarkation.

The technical service depots, more commonly referred to as branch depots, are specialized depots which handle supplies of one technical service of the Department of the Army. They include engineer depots, ordnance depots, quartermaster depots, etc., which are administered and operated under the Chief of the Technical Service of which they are a part.

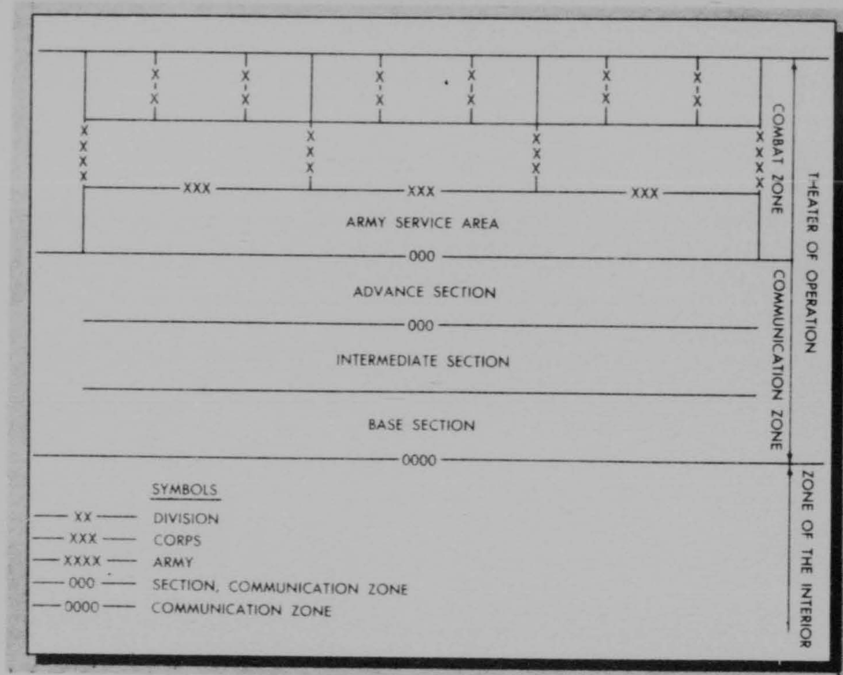

Figure 4—5. Typical Organization of Theatre Operations.

They are used exclusively for the procurement, storage, and issue of items of supply and equipment for which the particular technical service has been charged with procurement and supply responsibility.

The reserve depot, as the name implies, is a standby depot to be used in the event of future mobilization. At present the reserve depot is used to protect surplus property pending disposition; house war reserves, less active items, and various other stocks which may gradually be moved into the general distribution depot. The stocks of active items presently in the reserve depot will gradually be issued to the general distribution depot.

Army depots within a theater of operations are classified within one of the following categories:

Stock carried. Location.
Mission performed.

Considering theater of operations depots classified in accordance with the stock carried, there are two types: the general depot and the branch depot.

The **general depot** procures, stores, and distributes items of supply of two or more of the technical services.

The **branch depot** specializes in the procurement, storage and distribution of supplies of one technical service of the Department of the Army.

Depots classified in accordance with their location in a theater of operations are known as base, intermediate or advance depots, each of which is located within the communications zone of the theater. **Advance depots** are those Army depots within the communications zone, but nearest the combat zone. **Base depots** are located near the rear boundary of the com-

munications zone and generally in the proximity of ports of debarkation. **Intermediate depots**, as the name implies, are those Army depots which lie in the area between the base and advance depots.

Depots classified in accordance with their mission are known as issue, filler, key, and base depots.

An **issue depot** is normally located in the advanced section of the communications zone. It is assigned the responsibility for storing supplies within prescribed levels. It also issues such supplies to meet the needs of armies and other troops in a designated area of the combat zone and to troops and organizations in a designated area of the communications zone.

A **filler depot**, normally located in the intermediate section of the communications zone, is assigned the responsibility for storing the principal portions of theater supplies within levels as prescribed by the theater commander. Filler depots are responsible for replenishing supplies upon request from issue depots.

Key depots are depots assigned the responsibility for centrally storing the entire communications zone stock of selected items of supply and issuing supplies upon approved request.

Base depots are normally located in the base section of the communications zone and are assigned the responsibility for receiving, classifying and storing supplies shipped from ports of debarkation or from local manufacturers. They serve as a warehouse to clear ports of debarkation and for storage of excess theater stocks; they also replenish supplies of specified filler depots. (See Figure 4-5).

Supplies, both common and Air Force technical supplies, are divided into nine classes principally for logistic planning purposes and for supply instructions contained in field administrative orders.

SECTION VI—CLASSES—SALVAGE AND DISCIPLINE OF SUPPLY

1. CLASSES OF SUPPLY

The nine classes are designated by Roman numerals, letters I thru V followed by a capital A in the case of the four special Air Force classes. The following is a brief description of each of the nine classes of supply:

Class I. Supplies such as rations and forage, which are consumed by personnel and animals at an approximate uniform daily rate irrespective of combat operations.

Class II. Supplies and equipment, except Air Force technical supplies and equipment, for which allowances are established by authorized tables and which are not included in Classes IIA, IV, or IVA supplies.

Class IIA. Air Force technical supplies and equipment for which allowances are established by authorized publications and tables.

Class III. Fuels and lubricants for all purposes except aviation fuel and lubricants. This class includes petroleum products such as gasoline, kerosene, diesel oil, fuel oil, and greases.

Class IIIA. Aviation fuels and lubricants.

Class IV. Supplies and equipment, except Air Force technical supplies and which are not otherwise classified. Examples include such material as construction and fortification materials.

Class IVA. Air Force technical supplies and equipment for which allowances are not prescribed and which are not otherwise classified. As an example, additional aircraft with tactical units.

Class V. Ammunition such as small arms ammunition, grenades, mines, explosives such as dynamite, TNT blocks, fuses, and chemical warfare agents.

Class VA. Ammunition used exclusively by the Air Force such as bombs, aircraft rockets, pyrotechnics, aerial mines, special aircraft

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machine-gun and cannon ammunition.

The above nine classes in theater of operations may have depots that handle only that special class. Field orders will make reference to the above classes, informing units where that type of materiel may be requisitioned.

2. SALVAGE AND RECLAMATION

Salvage is property that is in such worn, damaged, deteriorated, or incomplete condition, or is of such a specialized nature that it has no reasonable prospect for sale as a unit, or is not usable as a unit without major repairs or alterations. Salvage has some value in excess of its basic material content because it may contain serviceable components or may have value to a purchaser who may make major repairs of alteration. Salvage property is composed of condemned, discarded, abandoned, or captured property including scrap and waste material, nonrepairable property, and abandoned private property.

To salvage means the saving or rescuing of condemned, discarded, or abandoned property and of materials contained therein for re-use, refabrication, or scrapping.

Salvage should be classified as promptly as possible as:

Serviceable.
Unserviceable and repairable.
Unserviceable and beyond repair.

Salvage therefore consists of materiel which can be used for its original purpose, either with or without repair, and materiel which can be converted to a substitute use, or which has value only as scrap for use as raw material. As soon as property is recovered, evacuated, and classified, and is determined to be serviceable or repairable, it should be so designated and removed from the category of salvage.

The movement of captured enemy materiel into supply channels is important, not only for use in the command or for scrap, but also to meet research and training requirements.

Regularly organized field maintenance units of all services will accomplish evacuation in connection with their own maintenance operations. They will also receive and inspect all items within their responsibility and which are recovered or evacuated by other units. After salvage has been collected and inspected, immediate steps, based upon the supply status and condition of each item, must be taken to:

Restore economically-repairable items to serviceable condition within the scope and capacity of the unit.

Evacuate serviceable items to the proper supply establishment.

Evacuate unserviceable economically-repairable items to the proper maintenance organization for repair and return to stock.

Evacuate irrepairable but reclaimable items to the proper maintenance organization for reclamation.

Evacuate uneconomically-repairable items and scrap to designated depots or other collection points.

Reclamation is the process of restoring to usefulness condemned, discarded, abandoned, or damaged materiel, or parts or components thereof, by repair, refabrication, or renovation, and returning such items to supply channels.

Reclaimed property, unless placed in service immediately, will be returned to supply channels. One of the important responsibilities that an armament officer must fulfill is to enforce "supply discipline".

3. SUPPLY DISCIPLINE

In the Service, the practice of saving and conserving is known as supply discipline. Like other disciplines, it should become a habit. It is an evidence of good leadership. Supply discipline is based upon a great military principle as old as history—economy of force. It means making a practice of using equipment and supplies carefully.

In general, the five basic principles of supply discipline which, when carried out effectively, will make all military personnel "cost conscious" are:

Use of supplies and equipment for their intended purposes only.

Proper care, preservation, and timely repair.

Conservation by using only the amount necessary to accomplish the desired result.

Safeguarding against loss.

Prevention of oversupply and hoarding.

Use of Supplies and Equipment for Their Intended Purposes Only

When the government plans to buy a new piece of equipment, experts consider what its purpose will be, and design it to those specifications. Into every item they build certain performance, within definitely stated limits. The manuals on the use of radar, engineer tools, flight control, and bombsight instruments, state the performance capabilities and limitations of each piece of equipment. To exceed, or even to approach, that limit except in emergency, is uneconomic and inefficient.

Proper Care, Preservation, and Timely Repair

Every piece of equipment, every item of supply, has a purpose and a place. If any equipment isn't where it should be, or isn't being used as intended, or isn't in good condition, the personnel responsible for it are not doing their job efficiently. Military personnel are issued the equipment needed to perform their jobs, whether training in gunnery, repairing a tank, driving a truck, piloting a jet fighter, or submerging a submarine. The smart gunner or mechanic learns what his weapons or tools are capable of doing and what their limitations are; he keeps them in good order and handles them only as they were built to be handled.

Following the manuals for protection of property and equipment is another way of practicing economy. When winter or summer oil is called for, when a patch is indicated—that is the time to do the job. Proper care also includes such daily requirements as keeping supplies covered, protecting machines from rust, driving cars, trucks, and other vehicles at reasonable speeds, and piloting planes and ships at their normal cruising speeds except in emergency.

Conservation

Proper utilization of equipment and supplies includes economy of effort. This principle of economy calls for using only the force necessary to do the job efficiently.

Being thrifty doesn't include "sending a boy to do a man's job." One does not use a handjack to raise a building, or a handsaw to hew a forest. No one is expected to tackle a rock formation with a pickax, when dynamite and a mechanical shovel are necessary. Every leader and every man should use just the right amount of equipment and supplies to do the the job adequately and efficiently. That is conservation. Any greater use of materials, time, or manpower is improper utilization.

Safeguarding Against Loss

When supplies and equipment are stored, every precaution for its safekeeping should be taken. Often government supplies are taken, innocently and unthinkingly. The intention on many occasions is to return a borrowed item after it has served the pleasure or requirement of the moment. But often the item is forgotten and never returned. Real economy may be made possible every day by the simple device of asking whether the use of this equipment is necessary to the mission of the individual or unit.

In addition to such unintended leakage is the theft of items for black market sale, or other illegal uses by individuals.

There is no sure cure for this loss, short of a high standard of moral conduct. That cannot be legislated, induced by threat of punishment, or brought about by soft or harsh words. It is a matter for the individual conscience. However, supply personnel can do much to safeguard against loss. This can be done by keeping their records properly, and by storing supplies and equipment so that they cannot be easily drained off, and by using a system of distinctive marking. All members of the armed forces can economize and prevent loss by refusing to connive or assist in removing supplies and equipment illegally.

Prevention of Oversupply and Hoarding

Another thing that everyone can do is to refuse to hoard supplies. A unit should request no more than is needed, and should turn

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back to a depot items no longer necessary to the functioning of the individual or the unit.

Hoarding of supplies dates back before the days of Caesar. Once men are in uniform, a considerable number become "pack rats." There is something about the idea of getting in line to obtain a pair of shorts, a couple of pencils, that makes even the most casual individual suddenly become obsessed with the idea that he had better get an "extra" supply. His peculiar reasoning is that there may not be any more when he returns the following day or week.

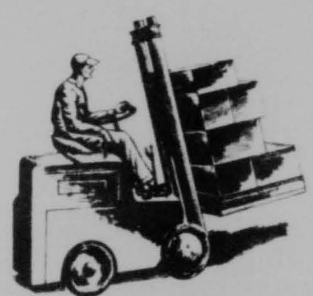
If the "pack rat" tendency applied only to the individual's equipment and supplies, it would be somewhat understandable. However, the idea is extended so that individuals are subject to this mental quirk when they draw supplies for their units.

Tight accounting methods and rigid inspection will correct a large part of the hoarding and thereby reduce the cost of national defense.

Some may say that it should be easy to figure out how many items are available in the military services, and how many are needed for the coming year. But the complexity of the military establishment demands that the supply agencies operate largely on anticipated requirements based on percentages and always projected a year or more ahead. Supply agencies attempt to make these estimates as realistic as possible and as close to the margin of economy as is humanly possible. Sometimes, because of unnecessary damage, unnecessary losses, or "runs" on the supply source, the supply agencies must purchase additional items at the last minute. If allowable, the money comes out of some other allocation for similar material, and somewhere in the process there is a shortage. Or, very possibly, if funds have been contracted for up to 100 per cent, the armed services must do without.

When supplies are lacking, someone must go short. Most often it is the man or the unit at the end of one of the supply line tentacles—and very often it is the man or unit needing supplies most. It is well to remember the wartime cry of the front lines for the food, cigarettes, or ammunition which on occasion did not reach them. Very often someone along the supply line was guilty of overrequisitioning, of hoarding, of misuse, or of carelessness. It all added up to a lack of teamwork and fair play. The men responsible were without a sense of justice to their buddies up front, who had discomfort and death as daily companions.

Proper use, proper care and repair, conservation, safeguarding against loss, and prevention of hoarding are not the only methods of economizing open to everyone in the armed forces. The field is almost unlimited. Proper care of one's health—preventive medicine—and keeping out of the guardhouse or the brig, can save the loss of many days. Safety around barracks, at homes, in vehicles, and planes can pay big dividends. Economy of life and man-hours is as important as economy of equipment and supplies.



CHAPTER 5—BASIC ELECTRICITY

SECTION I—DIRECT CURRENT AND THE NATURE OF ELECTRICITY

1. INTRODUCTION

Man discovered electricity many centuries ago. The ancient Greeks knew that when a piece of amber was rubbed on some fur or cloth, it acquired the property of attracting to it small pieces of paper, dust particles, and other light substances. It is from the Greek word "Elektron," meaning amber, that we obtain the word electricity.

In 1600 A.D., William Gilbert, an English scientist, discovered that many other substances, when rubbed together, possessed the same mysterious property of attracting light pieces of substances, paper, and dust particles. These substances, after being rubbed together are said to be electrified, or to have been given a charge of electricity.

This phenomenon can be proved by rubbing a small glass rod with a piece of silk cloth. Next, the rod is suspended from a silk thread so that it may swing freely. Another glass rod is rubbed with another piece of silk and suspended. When the two rods are near each other they will repel each other.

If a hard rubber rod is rubbed on a piece of flannel and is suspended near one of the glass rods the rubber rod and glass rod will attract each other. From this theory one may readily see that there are two types of charges. A negative charge was obtained with the rubber rod and flannel; a positive charge was obtained from rubbing the glass rod with the silk cloth.

From the foregoing experiment is established a very important rule pertaining to charges of electricity. Like charges repel, unlike charges attract. This basic rule should well be remembered, because the student of electricity will hear it many times.

The experiment with the rods dealt only with static electricity, which is of no value until it can be put to some useful work. Then it is no longer static electricity, but dynamic electricity. One may accomplish with dynamic

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electricity such things as fly aircraft, aim guns and turrets, give accurate range data, compute ballistics, and fire guns. It is essential, therefore, that the armament technician understand the important concepts contained in this course of electricity and electronics.

2. CONSTITUTION OF MATTER

Matter is any substance having weight and occupying space. The air a person breathes, the water he drinks, the bus in which he rides, his own body, all constitute matter. All matter is made up of one or more of ninety-two fundamental constituents, such as oxygen, hydrogen, iron, carbon and copper. These are known as elements because they cannot be broken into simple substances by chemical process. Matter appears in true forms. It may be a pure elemental substance; it may be a compound formed by the chemical union of two or more elements; or it may be a mixture of several elements or compounds which are bound together by chemical action. Irrespective of the form in which it is found, all matter can be broken down into molecules. The molecules of a compound always contain two or more atoms, while the molecules of some elements consist of a single atom.

Composition of the Atom

An atom is the smallest particle of an element which retains all the characteristics of the element. Although it is an extremely small particle of matter, the atom can be subdivided into a positive charged nucleus or core, and a cloud of negatively charged particles called electrons that revolve at a very high speed around the nucleus. Figures 5-1, shows that atomic structure of the simplest atom, the hydrogen atom, which contains one electron revolving around the proton which acts as the nucleus. The positive charge on the proton exactly equals the negative charge on the electron so that the atom is electrically neutral. In Figure 5-1$_2$ the nucleus contains two protons, and two neutrons. The charge on the two protons is neutralized by the two orbital electrons spinning around the nucleus. Thus, the neutralization of the positively charged protons is accomplished by the negatively charged electrons and the net charge

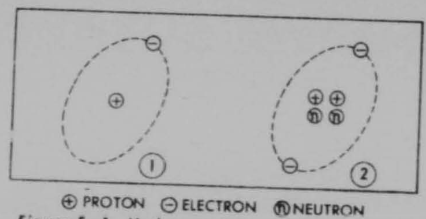

Figure 5—1. Hydrogen Atom, Helium Atom.

of the atom is consequently zero. The presence of the neutrons in the nucleus merely adds to the mass of the nucleus itself. Atoms of other elements are more complex than the two simple examples shown here. However, the only difference among the atoms of the several elements lies in the number and arrangement of the protons, electrons and neutrons of which each atom (with the exception of the simple Hydrogen atom) is composed. All atoms are electrical neutral since the number of positive charges always equals the number of negative charges. Since all matter is composed of atoms and all atoms are composed of positive and negative electrical charges, all matter is electrical in nature.

3. CONDUCTORS AND INSULATORS

In any material some of the electrons are not tightly held in their orbits. Such electrons, called free electrons, are able to move from one atom to another with relative ease. If a voltage is impressed across a substance, the free electrons are very quickly set in motion, causing a flow of electric current. In many materials such as glass, hard rubber, and porcelain, there are very few free electrons. These materials are known as insulators because it is difficult to force an appreciable electric current through them. In other materials, such as silver, copper, and aluminum there are many free electrons. These materials are known as conductors because an electric current can easily be passed through them.

4. THE ELECTRIC CURRENT

The free electrons in a conductor are moving constantly and changing their position in a haphazard manner. When a battery is con-

nected to the two ends of a copper wire, the random motion of the free electron is directed toward the positive terminal by the attraction of the positive voltage. Although the electrons themselves do not move through the wire at a high speed, the disturbance that causes them to drift along the wire progresses with the speed of light. This action may be compared to knocking down a column of tin soldiers; the soldiers do not move very far, but the initial disturbance travels down the line instantaneously. The battery forces the free electrons to drift from atom to atom along the wire only as long as it is connected. When it is removed, each atom is left with its proper number of electrons since those that were taken from the wire at the positive terminal of the battery exactly equal those that were added to the negative end of the battery. This drift or flow of electrons along a wire is called an electric current. **Since the electrons flow from negative to positive, the current is said to flow from negative to positive.** This statement is in contrast with the older conventional theory which assumed current flow to be from positive to negative. To avoid confusion in this manual, any reference to direction of current refers to **electron flow**, or **electron current flow**.

5. RESISTANCE

Since an electric current is a flow of free electrons in a material, those substances which have a large number of free electrons are able to pass a larger current with a given voltage impressed than can a substance with few free electrons. The measure of the numb[illegible] of free electrons in a material is prop[illegible]r[illegible] called resistivity. For a certain cross section and length, the resistance of a material can be calculated from its resistivity. The resistance of a material of a given resistivity is proportional to the length and inversely proportional to the cross sectional area. A unit in which resistance is deliberately lumped is known as a resistor. A resistor dissipates energy because some of the free electrons which are set in motion by the applied voltage collide with others and generate heat. Since the energy to set the electron in motion was obtained from the power source, the result of the collisions is to cause the resistor to absorb energy from the source. As the temperature of the resistor is increased, the random motion of the free electrons is increased but more collisions take place so that there are effectively fewer electrons able to flow as a current, therefore, the resistance of a material increases as the temperature is raised.

6. ELECTRICAL PRESSURE

The external force which tends to make the electrons move through a conductor is known as the electromotive force EMF. Electromotive force is electrical pressure. A practical example of electrical pressure or EMF is the dry cell, which when connected through a conductor to a door bell, causes current to flow through the bell. How electromotive force is produced is not a matter of concern at this time. However, it should be remembered that dry batteries, such as in flashlights or door bells have electromotive force. The unit of measurement of electromotive force is the volt. The number of volts are measured with a voltmeter, which means nothing more than a volt measure.

7. SUMMARY

From the preceding paragraphs, one should remember the following important points:

Unlike charges of electricity attract.

Like charges of electricity repel each other.

Electricity in motion is the movement of electrons.

Conductors have many free electrons and allow a free flow of current.

Insulators have few f ee electrons and tend to retard the flow of current.

Current in amperes (unit of flow) is the rate of flow of electricity.

Resistance in ohms (unit of resistance) is the opposition which regulates the flow of electrons.

Electromotive force (EMF) in volts is the moving force which causes the flow of electricity.

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SECTION II—ELECTROMOTIVE FORCE, CURRENT AND RESISTANCE

1. GENERAL

The relationship between the electromotive force, current, and resistance was discovered by a German scientist, George Simon Ohm, at the beginning of the nineteenth century. The unit of resistance was named in his honor.

The most important principle in electricity is Ohm's law. It is impossible to progress in electrical work of any kind without a clear understanding of this basic law and its application to the more common kind of electrical circuits. Ohm's law can be stated very simply, but considerable study is necessary to understand its application to the various electrical circuits.

2. CIRCUITS

In order to have a flow of current there must be a path, or conductor, in which electrons can move. This conductor must be in a form of a closed loop, thereby providing a continuous path for the flow of electrons from the negative source of EMF back to the positive side. This is known as a circuit. In every electrical circuit where there is a movement of electrons, pressure, and resistance are present and must be considered together in order to understand the circuit clearly. It must be remembered that Ohm's law applies just as much to any particular part of a circuit as it does to the entire circuit.

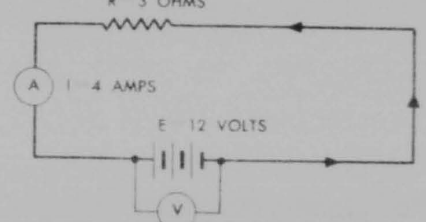

Figure 5–2. Simple Electrical Circuit.

3. OHM'S LAW

Ohm's law gives the relationship between voltage, current, and resistance in an electrical circuit. Ohm's law, simply expressed is as follows: **For any circuit or part of a circuit under consideration, the current in amperes is equal to the (EMF) in volts, divided by the resistance in ohms.** The following equation expresses this relationship:

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

The relationship expressed in the proper units is:

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

By common consent the following symbols are used:

E = Voltage
I = Current
R = Resistance

Using these symbols, Ohm's law may be written

$$I = \frac{E}{R} \quad R = \frac{E}{I} \quad E = I \times R$$

Application of Ohm's Law

Figure 5-2 is a diagram showing a simple electrical circuit. A wire is connected from the positive terminal of a 12-volt battery to the positive terminal of an ammeter, another wire from the negative terminal of the ammeter to the resistance, and a third wire from the resistance back to the negative terminal of the battery. There is a continuous path for the movement of electrons from the negative end of the battery. A voltmeter is connected across the battery so that its positive terminal connects to the positive terminal of the battery, and its negative terminal to the negative terminal of the battery. The wires connecting the various pieces of equipment are considered of negligible resistance in electrical problems unless a specific value is given.

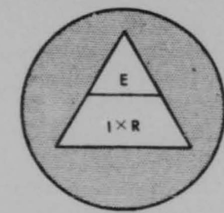

Figure 5–3. (E I x R).

The relationship expressed by Ohm's law is illustrated in the following problems, using Figure 5-3 as an example.

Problem 1—Find the current when the applied voltage is 12 volts and the resistance is 3 ohms.

E = 12 volts (given by voltmeter)
R = 3 ohms

Applying Ohm's law:

$$I = \frac{E}{R}$$

$$I = \frac{12}{3} \text{ or 4 amperes}$$

Problem 2—Find the resistance when the voltage is 12 volts and the current is 4 amperes:

E = 12 volts
I = 4 amperes (given by ammeter)

Applying Ohm's law:

$$R = \frac{E}{I}$$

$$R = \frac{12}{4} \text{ or 3 ohms}$$

Applying Ohm's law:

E = IR
E = 4 × 3 or 12 volts

4. SUMMARY

In applying Ohm's law to a circuit, if two of the values are known, the third can be determined by using the formula in one of the three forms.

Current

The current equals applied EMF divided by the resistance, or: amperes equals volts divided by ohms, or:

$$I = \frac{E}{R}$$

Resistance

The resistance equals the voltage divided by the current, or: ohms equals volts divided by amperes, or:

$$R = \frac{E}{I}$$

Voltage

The voltage equals the current times the resistance or: volts equals amperes times ohms, or:

$$E = I \times R$$

A simple way to remember the relationship between I, E and R is to set them up as shown in Figure 5-3. When it is desired to find an unknown factor, place a finger over the unknown on this form and read the relationship between the other two. Try it.

SECTION III—CIRCUITS

1. GENERAL

In armament and radar work it is often necessary to use two or more pieces of equipment in one circuit. These pieces of equipment may be connected in a number of different ways. All circuits, however intricate, may be divided into three general classes: **series circuits, parallel circuits,** and **series parallel circuits.** In a direct current (DC) circuit the only opposition offered to the flow of current is that due to resistance. The effects of combining several resistances in one circuit will now be considered.

2. RESISTANCE IN SERIES

A series circuit is one in which the resistances or other electrical devices are connected end to end so that the same current flows in

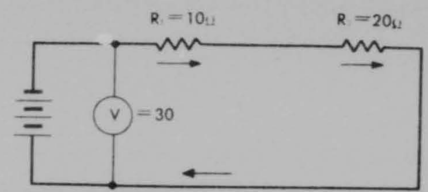

Figure 5—4. Series Circuit.

each part of the circuit. One of the most common circuits is the circuit shown in Figure 5-4.

In this circuit all the current which leaves the battery must flow through R1 and R2 and back to the source. In the current shown in Figure 5-4, the opposition to the current is the sum of all the individual resistors which are in series. Thus a 10-ohm and 20-ohm resistor connected in series make a total opposition of 30 ohms. This gives a law for the series circuit: In a series circuit the total resistance is the sum of the individual resistances. Thus for Figure 5-4

$Rt = R1 + R2$

Returning to Ohm's law, the same amount of current leaving the source must return, so in order to determine the current flow one must first find the total resistance which is 30 ohms. The voltage applied to the circuit is 30 volts as observed from the voltmeter. Then Ohm's law is applied: $I = \frac{E}{R}$

$E = 30$
$R = 30$

Then $I = \frac{30}{30}$ or 1 ampere of current.

It is frequently important to know the voltage across any one of the resistors in a series unit. This voltage may be measured with a voltmeter connected across the individual resistors as shown in Figure 5-5, calculated by Ohm's law.

In Figure 5-5, ammeter A will measure the current through the entire circuit and the values of Ea, Eb, and Ec will be the voltage across each piece of equipment. Ea, Eb, and Ec are called the voltage drops, or IR (current resistance) drops. The total resistance of the circuit in Figure 5-5 is 12 ohms.

Three laws of a series circuit, summarized below should be committed to memory:

In a series circuit the total resistance is the sum of the individual resistances.

In a series circuit the same current flows in each part of the circuit.

In a series circuit the sum of the voltages across the individual resistors is equal to the applied voltage.

3. PARALLEL CIRCUITS

In the series circuit explained in the preceding paragraph, only one path was provided through which the current might flow. There is, also a type of circuit which will provide more than one path through which current may flow. These circuits are known as parallel circuits. A parallel circuit is one in which one terminal of each element is connected to a common point to form one terminal of the system, and the other terminal of each element is connected to a second common point to form the other terminal of the system.

In Figure 5-5 the same voltage which is applied to R1 is also applied to R2 and to R3. This is true because the corresponding points of each resistor are connected to the same points, A and b, and the same difference in potential must exist between points "a" and "b" for all three resistances. This illustrates the first law of parallel circuit. In a parallel circuit the same voltage is across each element. (See Figure 5-6.) For Figure 5-6, $Et = E1 = E2 = E3$.

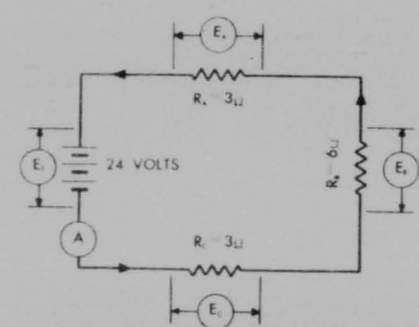

Figure 5—5. Voltage Relationship in Series Circuit.

If an additional path through which the current may flow is provided in a circuit, the total current in the circuit must be the original plus that of the added path. In Figure 5-6, if only R1 is connected to the source it is known by Ohm's law ($I = E \div R$). That current is $6 \div 3 = 2$ amperes. When R2 is added, the same voltage is applied to it as was applied to R1. The current through R2 must equal $6 \div 2 = 3$ amperes. The total current flowing in a circuit is now $2 + 3 = 5$ amperes. When R3 is added, the total current from the battery will be increased, another 3 amperes of current will flow now making the total current flow $2 + 3 + 3 = 8$ amperes. From these results, the following rule for a parallel circuit may be stated: **The total current in a parallel circuit is equal to the sum of the currents flowing in the individual branches.** For Figure 5-6

$It = I1 + I2 + I3.$

Since the total current in the circuit and the applied voltage are both known, the joint or combined resistance of R1, R2, and R3 may be calculated:

$$Rt = \frac{Et}{It} = \frac{6}{8} = .75 \text{ ohm}$$

From this result, another rule for parallel circuits may be stated: The joint or total resistance of a parallel circuit is equal to the applied voltage divided by the total current. In composing the total resistance Rt with the individual resistance R1, R2, and R3, Rt in this case equals .75 ohm and is less than either R1, R2, or R3. In a parallel circuit the total resistance of the elements is less than the resistance of the smallest element.

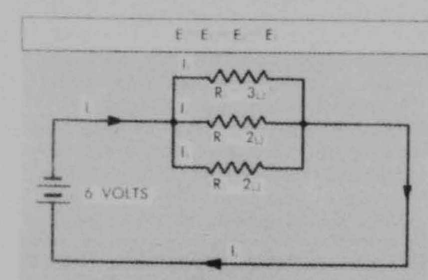

Figure 5—6. Parallel Circuit.

The Three Laws of a Parallel Circuit Should Be Memorized

In a parallel circuit the same voltage is across each element.

The total current in a parallel circuit is equal to the sum of the currents flowing in the individual branches.

The joint resistance of a parallel circuit is equal to the applied voltage divided by the total current.

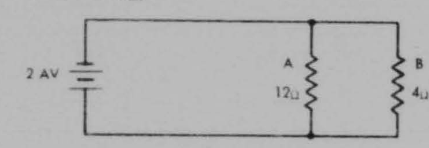

Figure 5—7. Parallel Resistors (unequal).

4. COMBINING PARALLEL RESISTANCES

A method of determining the total resistance of a parallel circuit was shown in the preceding paragraphs. This is satisfactory, providing the total current is known. Usually it is not, and other means must be used for finding the total resistance. The simplest case is that of several equal resistors connected in parallel. To solve this problem, divide the resistance of one piece of equipment by the number of pieces connected in parallel. If two 10 ohm resistances are connected in parallel the joint resistance offered by the combination is $10 \div 2 = 5$ ohms. If three 12 ohm resistors are in parallel $Rt = 12 \div 3 = 4$ ohms, and if five 10 ohm resistors are in parallel $Rt = 10 \div 5 = 2$ ohms. State as a rule: **The joint resistance of equal resistance connected in parallel is equal to one resistance divided by the number connected.**

Unfortunately, all equipment used in electrical circuits do not have the same resistance. Therefore, when different pieces of equipment are connected across a battery they do not all draw the same current. Two unequal resistors connected in parallel are shown in Figure 5-7.

The current through resistor A would be

$$Ia = \frac{E}{Ra} = \frac{24}{12} = 2 \text{ amperes}$$

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The current through resistor B would be

$$IB = \frac{E}{Rb} = \frac{24}{4} = 6 \text{ amperes}$$

The total current from the battery is equal to the sum of the current in the branches, or:

$$It = 6 + 2 = 8 \text{ amperes}$$

Ohm's law will give the total resistance offered by the circuit

$$Rt = \frac{E}{It} = \frac{24}{8} = 3 \text{ ohms}$$

Obviously, the rule for equal resistors in parallel could not be used for this circuit as the individual resistors A and B are not equal in value.

For such cases, another method has been found for the calculation of the joint resistance: The resistance of two resistors in parallel is equal to their product divided by their sum. Apply the new rule to the circuit in Figure 5-7

$$RT = \frac{\text{Product}}{\text{Sum}} = \frac{12 \times 4}{12 + 4} = 3 \text{ ohms}$$

which is the same answer found when the applied voltage was divided by the total current.

The product over the sum method may be applied to any two resistors in parallel whether they are equal or not. It is the most common used method of determining the resistances of a parallel circuit. This method may be extended to include three or more unequal resistors in parallel. First, determine the resistance of two of the resistors in parallel; then combine the results of these calculations with one of the remaining resistors by another application of the same rule. In each case the result of the previous calculation is combined with one of the remaining resistances until all the resistances are included. For example, consider the circuit shown in Figure 5-8. In this circuit, three unequal resistors are connected in parallel.

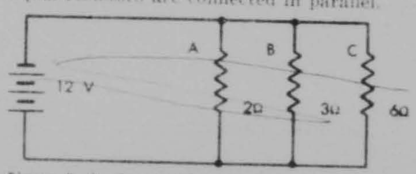

Figure 5-8. Parallel Resistors (unequal).

Applying the rule first to B and C:

$$Rt = \frac{\text{Product}}{\text{Sum}} = \frac{3 \times 6}{3 + 6} = \frac{18}{9} = 2 \text{ ohms}$$

Combine this result (2 ohms) with the remaining resistance (A) of 2 ohms.

$$Rt = \frac{\text{Product}}{\text{Sum}} = \frac{2 \times 2}{2 + 2} = \frac{4}{4} = 1 \text{ ohm}$$

This result (1 ohm) is the total resistance of the three resistors A, B, and C in parallel. This may be proved by calculating the total currents, and from this, the total resistance is calculated by Ohm's law.

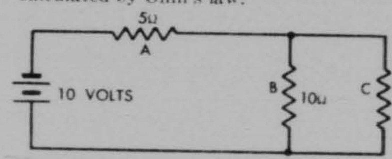

Figure 5-9. Series Parallel Circuit.

5. SERIES PARALLEL CIRCUITS

A series parallel circuit consists of groups of parallel resistors in series with other resistors. Any leg of a parallel group may consist of two or more resistors in series. Series parallel circuits may be solved by application of the rules already given for simple series and simple parallel circuits. To do this, the series parallel circuit is reduced to an equivalent, simplified circuit. Each group of parallel resistors is first replaced by its entire circuit and is then treated as a series circuit. (See Figure 5-9.)

The first step is to reduce the two parallel resistors B and C to an equivalent single resistance. As B and C are equal, divide 10 by 2, which gives 5 ohms as the joint resistance. The circuit is now a simple series circuit of two 5-ohm resistors. The total resistance is obtained by adding resistance A to the equivalent of B and C. This gives 5 plus 5 or 10 ohms as the resistance of the entire circuit. Knowing this, the total current is calculated by means of Ohm's law:

$$It = \frac{E}{Rt} = \frac{10}{10} = 1 \text{ ampere}$$

This 1 ampere flows through resistor A giving a voltage drop of 5 volts ($I \times R$). As the two parallel resistances have the same value, the

1 ampere of current divides equally between the two.

The IR drop across B equals $\frac{1}{2} \times 10$ or 5 volts and across C equals $\frac{1}{2} \times 10$, or 5 volts also. This demonstrates the rule that each element of a parallel circuit is across the same voltage. By following one complete path around the circuit, it can be shown that the sum of the voltage drops is equal to the applied voltage. Starting from the negative side of the battery there is a 5 volt drop in resistor A, another 5 volt drop in resistor B, before reaching the positive side of the battery. Following a path through resistor C will obtain the same result. Care must be taken to follow only one path at a time in tracing a circuit.

It is beyond the scope of this manual to try and solve a complicated series parallel circuits. This can only be done by a series of lectures and demonstrations.

SECTION IV—MAGNETISM

1. NATURAL MAGNETS

The ancient Greeks discovered that a certain kind of rock would attract or pick up bits of iron. They attributed this quality to supernatural causes and made no use of it except to create legends about it. This rock, often called magnetite, is one of the iron ores.

The Orientals learned that if a piece of magnetite were mounted in a horizontal plane and allowed to rotate, it would turn so that one end always pointed toward the north. The Europeans later learned of this discovery and used it as an aid to navigation. Because of this property, magnetite became known as a leading stone or a loadstone. Pieces of ore which have this magnetic property are called natural magnets.

2. ARTIFICIAL MAGNETS

The Europeans soon learned that they could use this natural magnetic ore to make magnets out of iron and steel. Such magnets are called artificial magnets. Artificial magnets are made by stroking a steel bar with a piece of loadstone. Making magnets by electrical means is discussed a little later on.

It has been found that the best magnets are made of steel. Even though iron is more easily magnetized than steel, it does not retain its magnetism so well. Since steel retains its magnetism better than iron, it is said to have greater retentivity than iron. Recent developments in the manufacture of new steel alloys have produced steels of exceedingly high retentivity. Cobalt steel and Alnico are examples of this development.

3. MAGNETIC POLES

If a magnet is dipped into iron filings, the filings will cling to it in tufts. These tufts are longest and greatest at the ends of the magnets and especially at the corners. Near the center, scarcely any filings cling to the magnet. The filings around each end of the magnet seem to line themselves up with lines of some kind of force being radiated from the end. This region about the end of the magnet is called the pole of a magnet.

If a magnet is suspended in air by a string tied about its center, the magnet will turn so that one of its poles points toward the north and the other pole toward the south. This is true of any magnet except a ring magnet. The two poles must be in some way different from each other, since the same pole always points towards the north and the other always points south. Therefore, they are given different names to distinguish them. The pole which points to the north is called the north pole and the conventional marking of this pole is N. The south pole is marked S. Any magnet will act to some extent as a magnetic compass.

If a long magnet is broken at the center and the two pieces dipped into iron filings, it will be found that each of the pieces has two poles, one at either end. It will also be found that one of these poles is a north pole, and one a south pole. The piece which contains the north pole of the original magnet will have a south pole in the end at the break; the piece containing the south pole of the original magnet has a north pole in the end at the break. Every magnet, except a ring magnet, has both a north

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and south pole. It may have more than one of either kind of pole, but it must have at least one of each.

4. MAGNETIC FORCE

Since bits of iron may be lifted by a magnet, the magnet must exert a force upon the iron. This force acts at a distance. This fact may be observed by noting the action of a magnet on iron filings. The magnet causes filings to move even though the magnet and filings are not in contact. The force acts through almost any substance, as can be demonstrated by moving a magnet beneath a glass plate on which are sprinkled iron filings. As the magnet is moved, movement of the filings is perceptible. Also, it can be shown that the force is mutual, for a magnet can be attracted to a firmly held piece of iron just as strongly as the iron is attracted to the magnet.

It might be thought that the strength of a magnet could be measured by its lifting power, but this is not true. Various conditions, other than the magnet itself, will vary its lifting power. Some of these conditions are: the kind of iron to be lifted, the shape of the iron body to be lifted, the manner in which the load is applied to the magnet, and the shape of the magnet. The accepted method of measuring the strength of magnets is by their action upon one another.

If a magnet (compass needle) is mounted so that it is free to swing in a horizontal plane, and the north pole of this compass needle is approached with the north pole of a bar magnet, the compass needle will swing until its south pole is as close as possible to the north pole of the bar magnet. See Figure 5-10. Now, if the magnet is reversed so that its south pole approaches the south pole of the compass needle (Figure 5-10), the latter will again swing until its north pole is in the nearest possible position to the south pole of the bar magnet. From these facts, the first law of magnetic forces may be stated: Like magnetic poles repel each other; unlike magnetic poles attract each other.

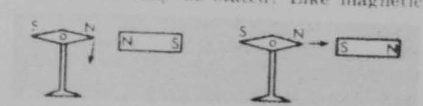

Figure 5-10. Magnetic Polarity.

5. MAGNETIC FIELDS

Since a magnetic pole acts as a distance upon other poles, there must be a space around every magnetic pole in which the magnetic force becomes evident as soon as another magnetic material is placed anywhere within that space. This space about a magnet, in which the magnetic force is evident, is called the field of the magnet or magnetic field.

In one sense, a magnetic field is like a stream of water. The water exerts no pressure until an object is placed into the stream, giving something against which it can push; yet the force is there awaiting an object upon which to act.

A magnetic field may be considered as a force. A force has direction, and so does a magnetic field. A magnetic pole placed in the field would move in the direction of the force. If it were a north pole it would move in one direction, and if it were a south pole it would move in the opposite direction. To find the direction of a field, the polarity of the pole placed in the field must be known. By convention, the positive direction of a magnetic field at any point is defined as the direction in which a free north pole, placed at that point, would tend to move.

The magnetic field at any point exerts a force on a free north pole at that point. Therefore, since a compass needle is acted upon anywhere on the earth, there must be a magnetic field surrounding the earth. The direction and intensity changes from point to point. This field is invisible, but for many purposes it must be indicated. Such representation is made by means of lines of force. If a free north pole is moved, it will trace a line of magnetic force from the north pole of the magnet to the south pole of the magnet, since it is repelled by the north pole and attracted by the south pole. A line of force may be defined as a line whose direction at every point through which it passes is the direction of the magnetic field at that point. Lines of force leave the magnet at the north pole and enter a magnet at the south pole,

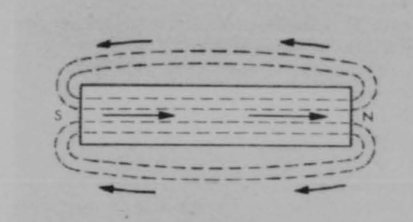

Figure 5—11. Lines of Force of a Magnet.

this being the conventional direction of the magnetic field (Figure 5-11).

For purposes of illustration, four lines of force are shown in Figure 5-11, two on each side of the magnet. Many thousands of lines actually exist for any magnet. Notice that the lines of force do not cross each other. Since the lines of force travel inside the magnet from south to north to complete their path, there are four lines of force at each of the poles of the magnet, and only two lines of force on either side. As the lines of force represent the strength of the magnetic field, it may be stated that the strength of the magnetic field is greatest at its poles. This can be proven experimentally.

6. RELUCTANCE

All magnets do not have the same strength; therefore the fields of various magnets do not contain the same number of lines of force. The number of lines of force must travel outside the magnet.

When a line of force leaves the magnet at the north pole, it must travel outside the magnet, through the air, to reach the south pole because lines of force do not cross one another. Air offers resistance to the lines of force. This resistance to magnetic lines of force is called reluctance. In addition to air, other objects give a certain amount of reluctance to lines of force. For example, copper offers considerable reluctance. In order to reduce the distance that the lines of force of a magnet must travel outside the magnet, and to concentrate the field of the magnet, most magnets used in radio or telephone work are bent in the shape of a horseshoe (Figure 5-12).

7. SHIELDING

Soft iron may also be used to protect an object from magnetic lines of force. This may be accomplished by placing the object in the center of a circle formed by soft iron. Any magnetic lines of force near this combination will take the path of least reluctance through the iron circle, and do not disturb the object. From this example, a statement can be made to the effect that soft iron may be used to distort a magnetic field. Any substance that offers less reluctance than does air to the magnetic lines of force can be used for the same purpose, but not so efficiently as soft iron.

8. MAGNETIC INDUCTION

If a magnet is dipped into iron filings, these filings will cling not only to the magnet but also to one another. This fact is explained by saying that the magnet has made the filings magnets by induction. Such induced magnetism is in most cases only temporary; it vanishes when the inducing magnet is removed. When magnetism has been induced into a substance by the use of another magnet, and this substance retains some of the induced magnetism after the inducing magnet has been removed, this retained magnetism is called residual magnetism. The amount of residual magnetism remaining in a substance depends primarily upon three things: the composition of the substance (the retentivity of the substance), the strength of the inducing field, and the length of time the substance is in contact with the inducing magnet.

Another method of making a magnet by induction is to stroke a retentive substance

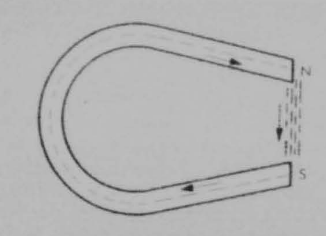

Figure 5—12. Horseshoe Magnet.

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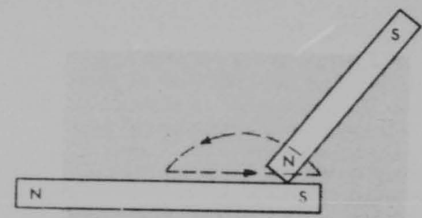

Figure 5—13. Magnetizing by Induction.

with a magnet, following the same direction of stroking each time (Figure 5-13). This method of induction can be understood more easily if the substance is imagined as composed of millions of molecules, each molecule in itself being a tiny magnet. As the north pole of the inducing magnet is drawn over the substance, it attracts the south poles of these molecules and turns them so that they align themselves in one given direction, thus creating a magnet by adding the combined magnetic strength of the individual molecules. Figure 5-14A represents the substance before magnetizing and Figure 5-14B represents the substance after magnetizing. As one portion of the substance is stroked with the north pole of the magnet, a south pole will be induced due to the law of repulsion and attraction of magnetic poles. A north pole will also be induced at the opposite side or end of the substance.

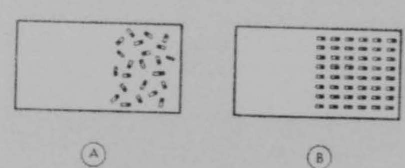

Figure 5—14. Molecular Magnets.

9. PERMEABILITY

It has been shown that soft iron, when placed between two magnetic poles, would allow an additional number of lines of force to pass through a space formerly occupied by air. The ratio of the number of lines of force which pass through a given space when it is occupied by a substance, to the number of lines of force passing through that space when it is occupied by air, is called the permeability of the substance. For all substances except magnetic substances, this ratio is approximately one. The permeability of magnetic substances is numerically always greater than one, and under certain conditions may be in the thousands. Example: Suppose a magnet would produce 100 lines of force through air, and would produce 1,000 lines of force when a soft-iron bar was placed in the field. The permeability of the soft iron would be 1,000 to 100 or 10. Permeability is represented by the symbol (Greek letter) mu.

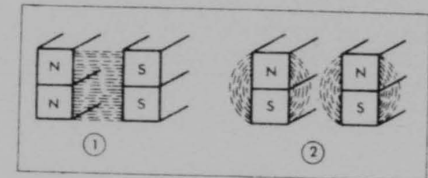

Figure 5—15. Compound Magnets.

10. GENERAL

In practice it is often necessary to place two or more magnets together to obtain a field strong enough to produce the desired results. Such a combination is known as a compound magnet. An example of such a magnet is the generator in the local-battery telephone. This generator uses either two or three magnets. In constructing a compound magnet, all the north poles are placed together, and all the south poles are placed together, thus forcing the field across the air gap. Figure 5-15¹ represents the proper method of placing two magnets together to form a useful field. Figure 5-15² represents the improper method of placing two magnets together to obtain a compound magnet.

Another type of magnet used is known as the ring magnet. This magnet is in the shape of a ring or square, and has no outside field, since the magnetic lines of force make their complete circle within this magnet. The ring magnet has a definite field direction, but no poles. However, if a piece is cut out of the magnet, definite north and south poles are established. The principal use of such magnets is in repeating coils and transformer

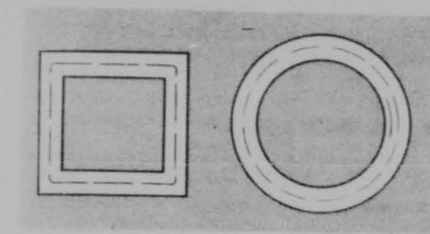

Figure 5—16. Ring Magnets.

cores. Two types of ring magnets are illustrated in Figure 5-16.

A substance that has been magnetized may be demagnetized by excessive vibration or heating. This fact may be explained by the molecular theory. Striking a magnet with a hammer jars the molecules and causes them to move into a jumbled position. Thus, heating or excessive jarring of a magnet will weaken or even completely destroy it. Equipment containing permanent magnets should be handled with reasonable care to prevent demagnetizing. Demagnetizing, either partial or complete, causes errors in measuring instruments and unserviceability in many other types of equipment.

SECTION V—ELECTROMAGNETISM

1. DEFINITION AND EFFECTS

Electromagnetism, in contrast to neutral magnetism, is the magnetic field of force set up around a conductor by the passage of an electric current through it. Every electric current produces a magnetic field which, in the case of a straight conductor, may be represented graphically, as in Figure 5-17. The lines of force about the wire are concentric circles. The intensity decreases with the distance from the conductor, and since the magnetic field is the result of the current flowing in the conductor, the strength of this field is proportional to the strength of the current flowing in the conductor. If the direction of the current through the wire is reversed, the direction of the lines of force will also be reversed.

The presence of a magnetic field around a current-carrying conductor may be demonstrated by placing a freely suspended magnetic needle (a compass) near it. The needle will tend to place itself at right angles to the conductor and parallel with the lines of force. Since a magnetic field, by definition, is the region in which a magnetic needle is acted upon by a force, it follows that the space surrounding the current-carrying conductor is a magnetic field.

In drawings and illustrations, the direction of current flow and the direction of the magnetic field generally are shown. In Figure 5-17, for example, the direction of the current flow in the left-hand drawing, as shown by a cross (arrow feathers), is into the paper. In the right-hand drawing the current is flowing from the paper as indicated by the dot (arrow point) in the conductor. On both drawings, the direction of the magnetic field is indicated by the arrows on the lines of force.

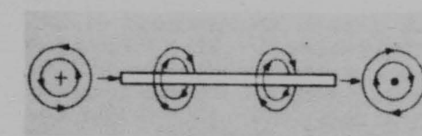

Figure 5—17. Magnetic Field Around a Conductor.

2. LEFT-HAND RULE

After the discovery of the relationship between the current direction and the direction of the magnetic field caused by the current, a simple rule was set up to find the direction of the magnetic field when the direction of the current is known. This rule is known as the left hand rule for determining the direction of the magnetic field about a current-carrying conductor, and stated simply, is as follows: Grasp the conductor in the left hand with the thumb pointing in the direction of the current flow; the fingers will point in the direction of the magnetic field.

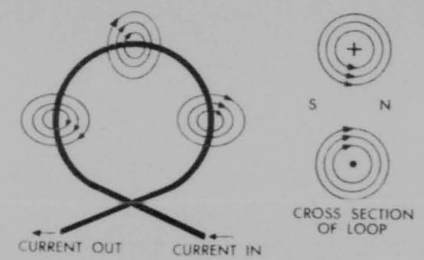

Figure 5–18. Magnetic Field Around a Loop.

3. EFFECT OF BENDING WIRE INTO LOOP

If the straight conductor in Figure 5-17 is bent into shape of a 1-turn loop as shown in Figure 5-18, all of the lines of force which encircle the wire must enter the plane of the loop on the one side and leave on the other. All the magnetic force, which in Figure 5-19 entered the paper beneath the conductor for its entire length, now is confined to the area within the loop. There is still the same number of lines of force produced by the length of conductor, but when bent into the shape of a loop the force becomes concentrated within the loop.

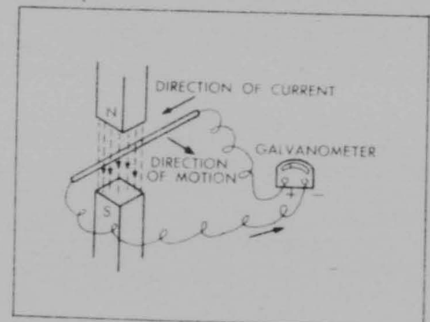

Figure 5–19. Electromagnetic Induction.

4. POLARITY OF SOLENOID

A coil or solenoid carrying a current has a north pole and a south pole just the same as a 2-pole bar magnet, and its polarity may be found by applying the left hand rule for determining the polarity of a solenoid. The rule may be stated as follows: If, direction of the flow of current, and the thumb is extended at a right angle to the fingers, then the thumb will point toward the north pole. If the current is reversed the poles will reverse.

5. ELECTROMAGNETS

An electromagnet may be defined as an iron core surrounded by a coil of wire. The iron in the core is used to reduce the reluctance of the magnetic circuit, and to develop a greater flux that could be developed if no core were used. This is true because the permeability of iron is approximately two thousand times greater than air. The word **flux** is often used in the remainder of the text, and it simply means magnetic lines of force.

A piece of iron can be visualized as containing millions of tiny magnets which, unless otherwise influenced, lie in a haphazard fashion so that they neutralize each other; there is no resultant magnetic field surrounding it. If the iron is exposed to the influence of a magnetic field, the little magnets turn, similar to a compass needle, their "N" poles pointing in one direction and their "S" poles pointing in the opposite direction so that the fields are additive. The degree of magnetization depends upon how completely these magnets can be "lined up." If the magnetizing force is weak, only a part of them will be swung into line, and a weak magnet results.

When the magnetizing force is removed, all of the molecular magnets do not return to their haphazard positions; thus, the piece of iron or steel still has polarity. This remaining magnetism is called residual magnetism. Pure soft iron possesses this quality to only a slight degree, while very hard steel possesses it to a very high degree. In other words, a permanent magnet is one so hard that its particles do not readily swing back to their original positions once they have been influenced by a magnetic field. The tendency of a relay to hold up its armature after the circuit has been opened is caused by the residual magnetism in the core of its electromagnet. Therefore, relay cores are usually made of iron having very little retentivity (soft pure iron or alloys having high permeability and low retentivity).

The rule for determining the polarity of an electromagnet is the same as for a solenoid.

It makes no difference whether the wire is wound in one layer or any number of layers; whether it is wound toward one end and then back over this layer toward the other end, or whether all layers are wound in the same direction. As long as the current circulates continuously in the same direction around the core, the polarity of the magnet will be unchanged.

6. LOSSES IN ELECTROMAGNETS

When the magnetism of an electromagnet is rapidly reversed, that is, when the direction of the lines of force is changed several times in rapid succession by reversing the direction of the magnetizing current, the iron core becomes heated and a certain amount of energy will be expended. This heating effect is due to two causes:

Hysteresis, which is a kind of molecular friction caused by a reversal in position of the minute molecular magnets which iron is thought to possess.

Eddy currents, which are currents produced by an EMF induced in metal when the metal is moved in a magnetic field, or when a magnetic field in the metal changes in intensity.

In order to reduce to a minimum the heating effects (and losses) due to eddy currents, the cores of electromagnets sometimes are composed of bundles of soft iron wires or sheets insulated from each other to hinder the eddy currents. These are known as laminated cores.

7. INDUCED ELECTROMOTIVE FORCE

In the preceding sections the source of EMF was assumed to be a battery. This was done for the sake of convenience and simplicity. However, as a source of commercial electrical energy on a large scale basis, the battery is relatively expensive and unwieldy, and it is necessary to use some other means of obtaining electrical energy in bulk. Probably the most common means of accomplishing this is through the use of the generator, which depends for its operation upon the phenomenon of induction. For the purpose of study, the subject of induction may be divided into two types, electromagnetic and electrostatic. In the present section, however, the student need concern himself only with electromagnetic induction, which may be defined as that phenomenon whereby an electromotive force is induced in any conductor that cuts across or is cut by a magnetic flux; or that is linked by a magnetic field which is changing in intensity. The EMFs generated by electromagnetic induction may be subdivided further as follows: The EMF resulting from relative motion between a conductor and a magnetic field of force; the EMF appearing in one circuit due to the variation of the magnetic field of force in a nearby circuit, known as mutual induction; and the EMF induced in a conductor by a change in the current in the conductor itself, known as self-induction.

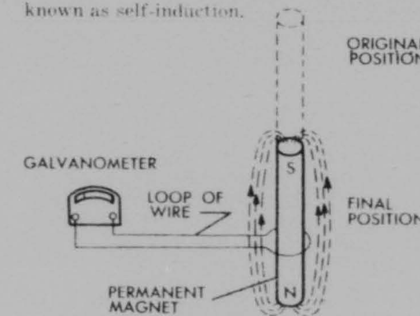

Figure 5–20. Electromagnetic Induction.

8. ELECTROMAGNETIC INDUCTION DUE TO RELATIVE MOTION BETWEEN CONDUCTOR AND MAGNETIC FIELD OF FORCE

When an EMF is impressed on a conductor and a current made to flow through the conductor, this current of electricity produces a magnetic field of force about the conductor. The reverse of this process is true also; a magnetic field can be made to create an EMF and thereby cause a current to flow in a closed loop. This creation of an EMF is accomplished by moving a conductor so that it cuts across lines of force, or by moving the lines of force so that they cut across the conductor. The relative motion is illustrated in Figures 5-19 and 5-20.

In Figure 5-19, if the conductor is moved back and forth between the pole faces so that its motion is parallel to the direction of the

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magnetic lines of force and therefore not cutting them, there will be no deflection on a meter connected to the conductor. This demonstrates that there is no induced voltage. As the angle between the lines of force and the path of the conductor is increased, the deflector on a meter increases until the maximum deflection is reached when the conductor is moving at right angles to the field. It may be stated, therefore, that a conductor moving parallel to magnetic lines of force will have no EMF induced in it, while one moving at right angles to the field will have a maximum EMF induced in it. In Figure 5-20 an EMF is induced by keeping the loop stationary and moving the field.

The value of EMF produced by a single wire, moving in a magnetic field, is very small unless the magnetic field is very strong. The same wire can be used to cut the same lines of force 1,000 times, by simply bending the wire in 1,000 loops so that other lengths of it will be exposed to the magnetic field. The wire would then be termed a 1,000-turn coil and would produce the same effect as though a single length of wire had been used in a field 1,000 times as strong as the original field.

Another factor which affects the value of the induced EMF is the speed of the movement. If the conductor is passed through a magnetic field, first slowly and then rapidly, it will be found that a much greater EMF is induced when the conductor is moved rapidly.

Sometimes it is said that electricity is generated by electromagnetic induction. In reality, the mechanical energy which is necessary to move the conductor through the lines of force or flux is transformed into electrical energy. It requires work or energy to move the conductor through the field if the coil is delivering current. A fundamental law of physics is that for every action or force in nature there is an opposite and equal reaction or force. From this law, it might be expected that if the process of induction is reversed, and a current is passed through a wire that is in a magnetic field, a force will be exerted on the wire tending to move it out of the field. That is exactly what happens and if the wire is free to move, it will be displaced from the field in a direction opposite to that required to induce

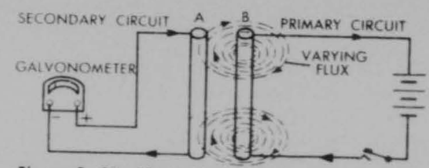

Figure 5—21. Mutual Induction.

an EMF. This action is termed motor action and is made use of in the moving coils of meters and electric motors.

9. MUTUAL INDUCTION

Mutual induction is the production of an EMF in a circuit as a result of the circuit being cut or threaded by a variable flux from a neighboring circuit. In Figure 5-21, circuit A has an EMF produced in it by mutual induction, because the circuit is being cut by the varying magnetic field or flux surrounding circuit B. If circuit B is suddenly connected to a battery, the current flowing through B will cause a magnetic field to build outward and encompass the other wire, A. An EMF, with polarity opposing that of B, will be induced in A during the time the field is building up, because the lines of force are moving outward from B to A. If the battery is then disconnected, another momentary EMF will be induced in A by the collapsing magnetic field. The polarity of the EMF induced by the collapsing field in A will be opposite to the polarity of the EMF induced by the initial expansion of the field. The first effect was caused by the wire being cut by lines of force expanding in an outward direction; the second effect was caused by the wire being cut by the lines of force while collapsing in the reverse direction. This second wire (A) has been termed the secondary circuit and the wire (B), which is used to create the magnetic field, is called the primary circuit. Any change of current in the primary either produces an expansion or contraction of the magnetic field about it. Hence, a current of varying strength will cause the field to alternately expand and contract and induce an EMF, both in the conductor (self-induction) and in neighboring conductors (mutual induction).

The value of the induced EMF depends upon the number of lines of force cut, the

number of turns of wire exposed to the field (if the wire is bent into loops), and the speed or time rate at which the lines are cut. It is thus apparent that the more suddenly the magnetic field is changed, the greater will be the induced EMF.

The induction coil, used in telephone apparatus, operates on the principle of mutual induction. The induction coil consists of two windings of insulated wire wrapped on a core of soft iron strips. The iron core is used to reduce the reluctance of the magnetic circuit.

In the study of induction it should be noted that there is absolutely no transfer of current from one circuit to the other. It is incorrect to say that the current of the secondary is induced from the primary circuit. Current cannot be induced by current; only EMF can be induced. The current that flows in the secondary is the result of the induced EMF.

Caution: A student should be very certain not to confuse magnetism and electricity as they are vastly different forces.

10. SELF-INDUCTION

Self-induction is the induction of an EMF in a conductor or circuit caused by changes in the current flowing through that same conductor or circuit. As current starts to flow through a straight conductor, a magnetic field is built up within and around the conductor. This field may be considered as surrounding the conductor in concentric circles and increasing in intensity, or as cutting the conductor as it builds up or expands. During the period that the flux is increasing in intensity or expanding, a voltage is induced in the conductor. This induced EMF is always in such a direction that it tends to oppose any change in the current in the conductor. When the current in one turn of a coil suddenly increases, the lines of force set up around this turn will expand. In so doing they will cut some or all of the neighboring turns of the coil, thereby inducing in them EMF, which is in the opposite direction to that of the original current. The reverse of this condition is also true; that is, when the current in this particular turn decreases, the field will shrink or contract, and in so doing will again cut all the neighboring turns, but in the reverse direction. The cutting of these turns by the decreasing field induces an EMF. Each turn of the coil acts on other turns, thereby greatly amplifying the effect of self-induction. Therefore, a coil will have much more self-induction than a straight conductor. The effect can be increased many times by the use of an iron core in the coil to decrease the magnetic resistance (reluctance).

Self-induction may be said to be that property of a circuit which tends to impede the introduction, or change, or current flow in a circuit. Self-induction is electrically very similar to mechanical inertia which tends to oppose setting up motion in a body and also tends to keep the body in motion after the force causing the motion is removed. An inductive circuit acts as though it possessed inertia; that is, it resists any change and especially a sudden change in the strength of the current flowing through it.

The EMF that is induced in a coil, when the current is increasing, is in opposition to the applied EMF. Being in opposition to the applied EMF, this self-induced EMF is sometimes called back EMF or counter EMF (CEMF). As soon as the current reaches its maximum value and the field is steady and unchanging, the CEMF will cease. However, the energy required to establish the magnetic field will be returned to the circuit when the current collapses. As the magnetic field collapses on the coil, an EMF is again induced in the coil, but in the opposite direction to that due to the expanding field. This induced EMF will be in the same direction as the original impressed voltage, that is, in such a direction as to prolong the current flow.

11. LENZ'S LAW

During the previous discussion, the conductor in which voltage is induced has been considered as cutting or being cut by the changing magnetic lines of force. It is equally correct to consider that the magnetic field links the conductor, and that any change in this linkage will induce a voltage in the conductor. A transformer is an example of induction by change in flux linkage. The principle of induction, both self and mutual, is expressed by

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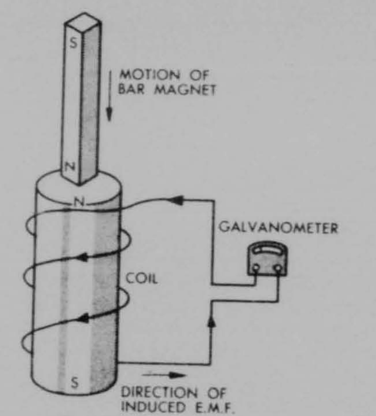

Figure 5–22. Direction of Induced EMF.

Lenz's law. This law is very important in electrical work and should be memorized. It can be stated as follows: **Whenever a conductor cuts across a magnetic field, or whenever the magnetic field linking a conductor changes, a voltage is induced in the conductor in such a direction that, if the circuit is closed, a current will flow and produce a flux to oppose the change in magnetic field.**

In the case of a linked circuit (mutual induction), this current will be distinct and measurable. In the case of self-induction this current will be combined with the current resulting from the applied EMF to produce a net or resultant current. To determine the direction of the induced EMF in a coil, it is necessary to label the coil with a pole that would repel the inducing pole. With this labeled pole as a factor, the left hand rule is applied to determine the polarity of the solenoid, as given in paragraph 9. (Also see Figure 5-22.)

12. MEASUREMENT OF ELECTRICITY

An electrical current may be defined as the movement of free electrons along a conductor. Since electrons are so small as to be invisible, the only means of detecting or measuring electricity is by the effects which it produces.

Effects

These effects are briefly reviewed as follows:

Heating effect. Whenever a current flows through a path offering considerable opposition (resistance) heat is produced. This heat may represent a useless loss of energy, or it may be used to advantage for lighting, cooking, soldering, etc.

Electromagnetic effect. A current produces a magnetic field in its vicinity, as can be shown by the attraction or repulsion of another magnetic field. The area affected in this manner is called the electromagnetic field of the conductor.

Chemical effect. Current, in passing through a chemical solution, will cause certain chemical action to take place. This effect is used in electroplating and electrotyping.

Physiological effect. The physiological effect is shown in the reaction of the human body to an electrical current passing through it.

Use in Measurement

Of the four effects mentioned, the first three can be used for the measurement as well as the detection of electricity. The fourth effect is a physical reaction of the human body and is impractical for precise measurements of electricity.

13. STANDARD MEASUREMENT

The chemical effect, since it is entirely independent of temperature, pressure, mechanical considerations, or physical considerations, is used as the standard with which to define the unit of current. Although used as a standard, the chemical method is not at all suitable for ordinary measurements as it takes time and requires very exact measurements of weight and time.

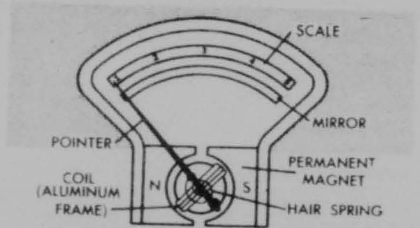

Figure 5–23. D'Arsonval Galvanometer.

Eliminating two of the effects because of their impracticability leaves only the thermal and electromagnetic effects. Since either of these two methods gives almost instantaneous measurements, with the minimum amount of skill necessary on the part of the measurer, virtually all of the common measuring instruments employ one of these two methods in their operation.

14. D'ARSONVAL GALVANOMETER

The D'Arsonval galvanometer, in its simplest form, consists of a coil of wire suspended between the two poles of a permanent magnet. As a current is passed through the coil, a magnetic field is set up around the coil and the coil now has a definite north and south pole in accordance with the right-hand rule. The coil will then turn, attempting to align itself so that its lines of force are parallel to the lines of force between the north and south poles of the permament magnet. Practically all meters employing the electromagnetic effect are based on the principle of the D'Arsonval galvanometer.

In the Weston-type DC meter, shown in Figure 5-23, the D'Arsonval principle of movement is employed. Certain structural improvements are embodied which provide a maximum of ruggedness with a minimum loss of sensitivity. In order to reduce friction, the coil is pivoted on watch jewels. The coiled hair spring tends to keep the coil from turning, thereby providing a force which resists that set up by the reaction between the magnetic fields of the coil and the permanent magnet. The coil and pointer are mechanically balanced so that the instrument may be used in any position. A mirror is placed next to the scale and beneath the pointer so that errors in reading the scale may be avoided.

For a time after the current is applied, the inertia of the coil and the resilience of the hair spring tend to cause the pointer to oscillate about the reading point on the scale. To reduce this tendency, a process called damping is required. The damping process does not interfere with the free movement of the indicator, but reduces the number of oscillations. Air vanes are effective damping devices, but in most meters a closed conducting loop, usually the frame on which the coil is wound, acts as a damper. As the coil moves in the strong field of the permanent magnet, an EMF is induced in the aluminum frame; resulting current produces a magnetic field that opposes the movement of the entire coil structure, thereby acting as a brake to keep the pointer from oscillating. When the pointer is at rest, there is no current induced in the aluminum frame.

In studying the action and construction of DC meters, the question might arise as to the difference between ammeters and voltmeters, since they both employ the D'Arsonval galvanometer principle of movement. In a galvanometer there is no provision for measuring the amount of current flowing through the coil. In this respect, the galvanometer acts more as a detector of current than a measurer. The ammeter is a galvanometer which has been calibrated in amperes so that the amount of current can be read directly from a scale. The voltmeter is a galvanometer calibrated in volts, and is so constructed that the small amount of current necessary to deflect the pointer is in proportion to the voltage being measured.

It must be remembered that when the electromagnetic type of ammeter or voltmeter is used, it consumes energy and becomes, in reality, a part of the circuit being measured. The amount of power consumed in many cases is negligible, and does not materially affect the accuracy of the measurement. However, when it is necessary that there be absolutely no current drain, other devices must be used.

15. AMMETERS

The galvanometer is very sensitive. It is so sensitive that a relatively small current flowing through its coil will drive the needle (Figure 5-23) all the way across the scale. This is because the only opposition to the movement of the coil and pointer is the tension of the coiled spring and the friction of the jeweled pivot. In DC instruments, the current required to give full-scale deflection of the galvanometer may be from 0.0001 to

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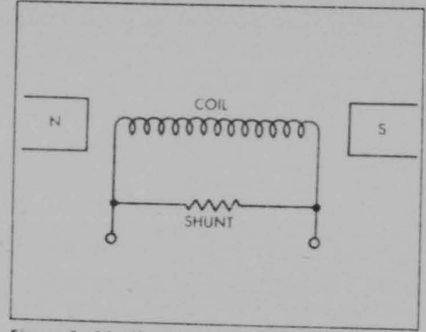

Figure 5—24. Shunt Connection for Ammeters.

0.035 amperes. Since the ammeter is used to measure larger currents than this, and because the ammeter must always be connected in series, it is necessary to shunt most of the current around the coil, allowing only a definite percentage of the total current to pass through the coil of the meter. This shunting or diversion is accomplished by putting a low resistance path in parallel with the coil of the meter. This additional path is called a shunt. The shunt circuit illustrated in Figure 5-24 shows that a parallel circuit is made with the resistance of the coil as one branch, and the resistance of the shunt as the other branch. The amount of current in each branch will depend on the individual resistance and the voltage applied.

By changing the resistance of the shunt, the range of the instrument can be extended so that the ammeter can measure many times the amount of the current necessary for full-scale deflection of the pointer. This is done by providing a shunt having lower resistance than the coil, thereby causing most of the current to flow through the shunt, but allowing enough through the coil to provide a readable deflection of the pointer.

In determining the size of shunt necessary, Ohm's law as applied to parallel circuits is used. For example, in the circuit shown in Figure 5-25, Ra represents an ammeter coil which has a resistance of 0.02 ohms. When 0.01 amperes flows through the coil, the ammeter gives full scale deflection. It is desired to measure 0.5 amperes of current with the meter and the problem is to find the value of shunt, Rs, necessary to increase the range of the instrument from 0.01 to 0.5 amperes. Since the coil itself can carry 0.01 amperes, the amount of current which must flow through the shunt is 0.5 − 0.01 or 0.49 amperes. The voltage drop across the ammeter coil, Ra, is calculated by applying Ohm's law to the circuit. This equals 0.01 × 0.02 or 0.0002 volts. Since the shunt, Rs, is in parallel with Ra, the voltage drop must be the same across the two resistances. Therefore, dividing the voltage drop by the current through the shunt will give the resistance necessary in the shunt 0.0002 ÷ 0.49 = 0.0004 ohms.

If the maximum reading of a meter is changed, the scale of the meter must also be changed, or a multiplying value calculated for converting-scale readings. For example, suppose an ammeter which reads a maximum of 3 amperes is changed by the addition of a shunt, so that the maximum amount of current which can be measured is 30 amperes. The shunt added to the meter has a multiplying value of 10. Hence the readings on the 3-ampere scale would be multiplied by 10 in order to obtain the correct value of current.

16. VOLTMETERS

When the galvanometer is used as part of the voltmeter, the objective is to reduce the amount of current which will flow through the voltmeter to not more than the amount of current required to drive the galvanometer needle all the way across the scale. Since the resistance of the galvanometer coil is not very great, a relatively small voltage applied to the coil would produce enough current for a full scale deflection. Therefore, resistance is connected in series with the coil. This resistance is usually known as a multiplier.

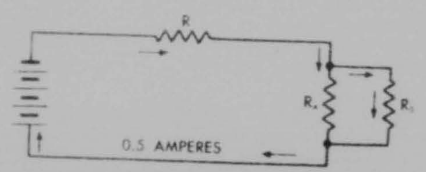

Figure 5—25. Action of Ammeter Shunt.

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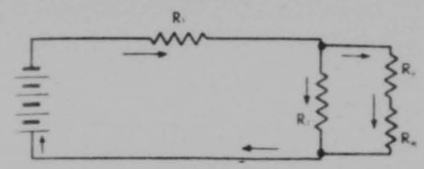

Figure 5—26. Action of Series Multiplier.

The circuit diagram of a multiplier and voltmeter coil, connected to measure the voltage drop across a resistor R_2, is illustrated in Figure 5-26. R_v represents the resistance of the voltmeter coil and R_m represents the resistance of the multiplier. R_v and R_m are in series and form a parallel circuit with the resistor to be measured. Therefore, a large value of R_m in this parallel circuit will force most of the current to flow through the resistor R_2, and will allow only a small value of current to flow through R_v and R_m.

The range of a voltmeter may be changed by varying the value of the multiplier. For example: A voltage drop of approximately 75 volts is to be measured and the only available voltmeter is one with a 10-volt scale reading. This meter can be converted to a 100-volt scale reading by the proper addition of a multiplier. To determine the value of multiplier, the ohms-per-volt value of the meter must be known. This value is usually stamped on the case; the ohms-per-volt value of voltmeter 1-50 being 100. When the ohms-per-volt value is now shown, it may be determined as follows: An ammeter is placed in series with the voltmeter and the amount of current necessary to produce full-scale deflection is determined. With this value, the resistance of the voltmeter is computed. This resistance is divided by the number of volts measured at full scale deflection. Assume that 0.01 amperes of current produces full-scale deflection on a 10-volt scale meter. The resistance of this meter is:

$$R_v = \frac{\text{Full scale reading in volts}}{\text{Current necessary to produce full scale deflection}}$$

$$R_v = \frac{E_v}{I_v} = \frac{10}{0.01} = 1{,}000 \text{ ohms}$$

The ohms-per-volt value of this meter is:

$$R \text{ per } V = \frac{\text{Resistance of meter}}{\text{Full scale reading in volts}}$$

$$R \text{ per } V = \frac{R_v}{E_v} = \frac{1000}{10} = 100 \text{ ohms per volt}$$

With the resistance and the ohms-per-volt value of the meter determined, the value of the multiplier to be used is given by the following equation:

$$R_m = (E \times R \text{ per } V) - R_v$$

(where E is the voltage to be measured)

The value of the multiplier to convert the 10-volt meter to a 100-volt meter is

$$R_m = (11 \times 100) - 1000 = 9000 \text{ ohms}$$

Therefore, it is necessary to add a multiplier of 9,000 ohms in series with the voltmeter to increase the range of this instrument from 10-volt scale to 100-volt scale. All readings then will be multiplied by 10.

It is not to be assumed that the ohms-per-volt method of computing multipliers is the only method to be used. The impracticability of measuring the current flow might prohibit its use in some cases. The application of Ohm's law to series circuits may always be used to determine the value of multipliers.

17. SENSITIVITY OF METERS

The sensitivity of a meter depends on the amount of current necessary to operate the moving element of the meter. The meter requiring the least amount of current for deflection is considered to be the most sensitive.

Since an ammeter is connected in series in a circuit, the voltage drop across the ammeter is a voltage loss. This voltage drop is dependent upon the resistance of the ammeter; therefore, in order to keep this loss at a minimum, the resistance of ammeters is kept at the lowest possible value.

Shunts and multipliers used in the laboratory meters are generally contained in the case of the instruments. Some meters, however, are equipped with outside terminals which provide connections for the use of external shunt and multipliers.

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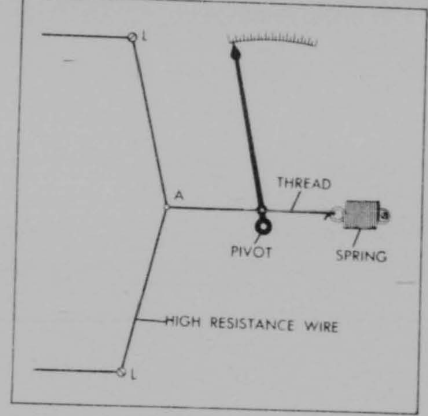

Figure 5–27. Hot-Wire Meter.

18. HOT-WIRE METERS

In the hot-wire meter the thermal or heating effect of electricity is used. The principle of the hot-wire meter is that when a metal is heated it expands, and when cooled it contracts.

The simple schematic diagram of a hot-wire meter is shown in Figure 5-27. The connections to the meter are made at L and L'. As the current flows through the meter, the resistance wire is heated. This heat expands the wire, and the spring pulls the needle over the scale by means of the thread. This is an inexpensive type of meter and is accurate to approximately 10 per cent of the full-scale reading.

19. THERMOCOUPLE METER

The thermocouple is probably the simplest source of an EMF but is of little practical use as a source of electrical energy. A simple illustration of the thermocouple principle is shown in Figure 5-28.

Almost every combination of dissimilar metals will give the thermocouple effect, but some combinations are better than others. Bismuth and antimony, constantan and copper, copper and nickel are combinations that are frequently used as thermocouples.

In a thermocouple meter, the heat is pro-

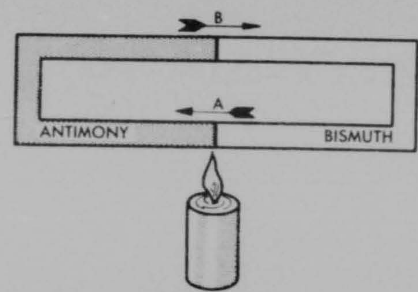

Figure 5–28. Thermocouple.

duced by a current passing through a resistance wire which, being in contact with the thermocouple at the junction of the two metals, heats it and thereby generates an EMF. The EMF generated actuates a meter of the moving-coil type, Figure 5-29.

The thermocouple meter is accurate to approximately 1 per cent. They are more expensive than the hot-wire type, and give much better results. Both the hot-wire meter and the thermocouple meter may be used to measure alternating current or direct current.

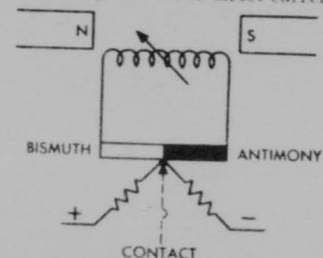

Figure 5–29. Thermocouple Meter.

20. VACUUM-TUBE VOLTMETERS

All of the meters described in the preceding paragraphs require current for their operation. In circuits where the amount of current drain must be at an absolute minimum, the vacuum-tube voltmeter is used. In radio circuits, where the amount of power is very small, the use of the ordinary meter would unbalance the circuit so that the measurement taken would not indicate the true operating conditions.

In the vacuum-tube voltmeter a vacuum

tube is used in connection with a moving-coil-type meter. The vacuum tube acts as an amplifier, drawing a very small amount of current from the circuit and increasing this current a sufficient amount to actuate the meter. For this reason, the meter used in the vacuum-tube voltmeter need not be as sensitive as the ordinary meter and consequently can be more ruggedly constructed.

The vacuum-tube voltmeter may be used for either AC or DC measurements. It can also be adapted for use in measuring current and resistance as well as voltage.

21. POWER AND WORK

Power is an important factor in everyday life, and particularly in the communication field. An understanding of the fundamental physical laws of energy is highly important to the student in solving problems in electrical power.

Energy

Energy is not made or destroyed, but exists in one form or another as a constant amount for the whole universe. This is a fundamental law known as the law of conservation of energy. This purely physical fact should not be confused with the practical fact that great quantities of energy are converted daily into forms no longer available to man, and thus are lost for practical purposes. The expression, "energy is expended or dissipated," is commonly used, and for all practical purposes is often true. Heat energy, electrical energy, mechanical energy, and light energy are some common forms of energy.

Energy can be converted readily from one form to another. This is the law of correlation of energy. An example illustrating this law is the electrical power plant. First, the chemical energy of the fuel becomes heat energy, which the boiler and turbine convert into mechanical energy. The generator then transforms this mechanical energy into electrical energy. In the form of electricity, the energy can be distributed over large areas for the convenience of man. Electrical energy is converted to heat energy by the electric iron, to mechanical energy by the motor, and to light and heat energy by the incandescent lamp. These are only a few examples of the transformation of energy in every-day life.

Force

Force is that which tends to produce motion, a change of motion, or change in shape of matter. Force is "push" or "pull." If a person pushes against a box, it may or may not move, depending upon the amount of muscular force exerted. If this push were exerted against a heavy stone wall, the wall would not move, yet force would be exerted. An example of electrical force is the dry cell. With no circuit connected to the terminals, there is an electromotive force of 1.5 volts between the terminals. This force is insufficient to overcome the resistance of the air between the terminals; therefore, no motion of electricity results. If a flashlight bulb is connected between the terminals, a current will flow through the electrical resistance of the filament. This motion of electricity is due to electrical force.

Work

When a force overcomes a resistance and causes motion, work is done. Regardless of force exerted, if no motion results there is no work done. The operation of a pile driver illustrates mechanical work. When the weight of the driving hammer is lifted against the force of gravity, work is done. This work stores energy in the weight, and while the weight is suspended, ready to drop, it possesses energy. The weight, while suspended, is exerting a force, but is doing no work. When it is released it drops, and upon striking the pile, does work. The amount of work done is measured by the product of the force exerted times the distance the body moves. The unit of work is called the foot-pound. The work done in raising a weight of 1 pound a distance of 1 foot, against the force of gravity, is 1 foot-pound. Raising 10 pounds 10 feet would be 10 pounds × 10 feet or 100 foot-pounds. Force performs work only when exerted through a distance or overcoming a resistance. It makes no difference how much time is required to do work, as long as the work is done. All work, whether chemical, mechanical, thermal, or electrical, can be expressed in foot-pounds. Work is in-

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dependent of time, and whether the work is accomplished in one hour or one year, the amount of work is not changed.

Power

Power is the rate at which work is done. To distinguish between work and power, the pile driver is again used as an example. It is necessary to expend considerable energy on the pile to drive it even a short distance. The machine requires considerable work over a period of time to raise the weight. Suppose the machine was designed to raise the weight in 10 seconds, and then it became necessary to change the machine so that the weight could be raised in 5 seconds. It would require twice as much power to raise the weight in 5 seconds. Power is work divided by time. The unit of electrical work is the **joule**, and the unit of electrical power is the **watt**. As a comparison, 746 watts are equivalent to 1 mechanical horsepower.

The discussion of power and work may be summarized as follows:

Energy is the capacity to do work. Work is force acting through a distance. Power is the rate of doing work.

Energy cannot be destroyed, but can be transformed from one form to another.

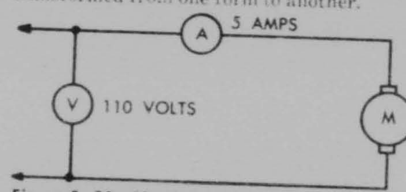

Figure 5–30. Circuit for Measuring Power.

The Watt

The watt is the unit of electrical power, and is equivalent to 1 ampere of current at a pressure (EMF) of 1 volt. Watts = volts × amperes, or DC power = IE. By the use of this formula, the power consumed by an electrtical device can be determined if the current and voltage are known. For example, consider the motor in Figure 5-30. To find the power, one substitutes the readings of the voltmeter and ammeter in the equation. I = 5 and E = 110, therefore P = IE = 5 × 110 = 550 watts. A wattmeter would be used if available, because it reads directly in watts.

Power Losses

The most common loss of power in electrical work is that which is due to the heat developed when current is flowing through a resistance. This heat is usually dissipated into the air and lost for useful purposes, except when the resistance is used for heating. Electric ovens, soldering irons, and filaments of vacuum tubes are examples of this use of heating. Since all conductors have some resistance, transmission lines and circuits should be designed to minimize these losses. An example of equipment where great losses are tolerated to accomplish a given purpose is a home radio receiver. The receiver may consume more than 100 watts of electrical power, yet more than 3 watts of sound power from the speaker would be intolerable. Most of the loss is in heat energy, and it is for this reason the radio sets are well ventilated. Electric motors have losses due to friction and resistance of winding; therefore, the mechanical output can never equal the electrical input. The output of any power consuming device, divided by the input, and multiplied by 100, will give its power efficiency. No machine can be 100 per cent efficient.

Resistance Losses

Resistance losses are an important consideration in communication work. The resistance used must be capable of radiating the heat generated without becoming hot enough to burn insulation or start fires. It is for this reason that resistors are usually rated in watts as well as ohms. This wattage rating indicates the safe wattage in heat that the resistor will radiate in free air without becoming damaged by heat. Resistors are often inclosed and may cause trouble in other parts of the equipment, due to poor radiation of heat.

From the power equation, P = IE, other very important power equation may be derived. Substituting IR for E, the power equation becomes $P = I^2R$. Substituting $\frac{E}{R}$ for I, the power equation becomes, $P = \frac{E^2}{R}$. These three power equations are commonly used.

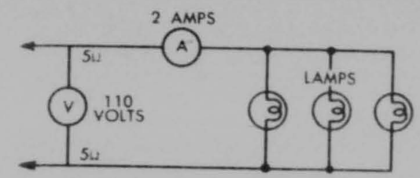

Figure 5–31. Parallel Circuits.

Electricians often refer to Figure 5-31, parallel lamp circuit, to the I^2R losses of a circuit, which is a short way of saying "the power lost in the circuit due to current through the resistance." An example of a practical use of the equation $P = I^2r$ is as follows: In Figure 5-31, the circuit is drawing 2 amperes and the line resistance is 10 ohms. The power loss in the line is to be determined. The joint resistance of the lamps is 45 ohms.

$$P = I^2R$$
$$I = 2 \text{ amperes}$$
$$I^2 = 4$$
$$R = 10 \text{ ohms}$$

therefore, P = 4 × 10 = 40 watts.

An example of the practical use of the equation $P = \frac{E^2}{R}$ is as follows: In Figure 5-32, a 20-ohm resistor is required to reduce the 12-volt battery voltage of a combat car to 6 volts for lighting a 6-volt radio tube. The wattage rating required of the resistor is to be determined:

$$E = 6 \text{ volts}, E^2 = 36, R = 20 \text{ ohms}$$

$$P = \frac{E^2}{R}$$

$$P = \frac{E^2}{R} = \frac{36}{20} = 1.8 \text{ watts}$$

In this example, any standard size of resistor rated at greater than 1.8 watts could be safely used. This equation is commonly used in practice, because all that is required is a voltmeter reading across a resistor to determine how much power is being dissipated in the resistor.

Since power is the rate of doing work or consuming energy, the length of time power is being used is the true measure of energy consumed. It is common practice to purchase electrical energy by watt-hours, watts × hours, or kilowatt-hours, $\frac{\text{watts} \times \text{hours}}{1000}$. A 100-watt lamp requires 100 watts of power for proper operation, and consumes 100-watt-hours of energy in 1 hour. In terms of kilowatt-hours, the lamp uses $\frac{100}{1000} = 0.1$ kwhr in 1 hour, or 1 kwhr for 10 hours of operation.

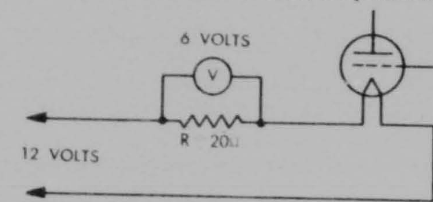

Figure 5–32. Vacuum-Tube Filament Circuit.

22. SUMMARY

The watt is the electrical unit of power, and is equal to volts times amperes.

Heat is a power loss, and is sometimes referred to as I^2R loss, or copper loss.

The output of any machine can never be equal to the input to the machine.

Efficiency is equal to the output of a machine divided by the input to the machine times 100.

The watt rating of a resistor should never be exceeded. Never allow enough current to flow through a resistor so that the current squared times the resistance will exceed the watt rating of the resistor.

Electrical energy is purchased in terms of watt-hours or kilowatt-hours.

23. WATTMETERS

The wattmeter is an instrument used to measure power in a circuit. Since the amount of power present in a circuit is dependent upon both the voltage and the current, a wattmeter must measure current and voltage at the same instant.

The wattmeter is a combined voltmeter and ammeter. It has two fixed coils in series to provide a magnetic field, and a movable coil which turns in this field. The fixed coils are placed in series with the load and may be termed the

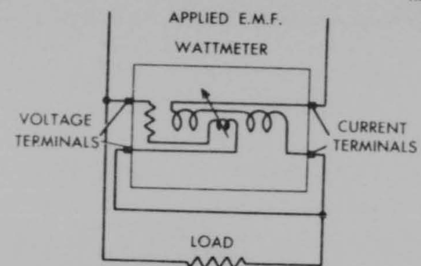

Figure 5—33. Wattmeter.

current-measuring element of the wattmeter.

The movable coil is connected in parallel with the load, and therefore can be considered as the voltmeter element of the instrument. The deflection of the pointer attached to the movable coil is proportional to the value of the voltage times the current, since the force acting upon the coil is the result of the magnetic fields of both the fixed and movable elements. Figure 5-33 illustrates the arrangement of the coils and the connections necessary.

When placing a wattmeter into a circuit, care must be taken that the four terminals are properly connected. Normally, the four binding posts are designated as + and — current-circuit (ammeter) binding posts, and + and — potential-circuit (voltmeter) binding posts.

SECTION VI—GENERATORS

1. GENERAL

A generator is a machine which converts mechanical energy into electrical energy. The mechanical power source may be a steam engine, an internal-combustion engine, or a steam or water turbine. The electrical power may be either direct current or alternating current, depending on the construction features of the machine; yet, in principle, the rotating coils and magnetic field through which they turn are the same for both types of machine. The difference between AC and DC generators is the method by which the current is taken from the machine.

The amount of EMF induced in a conductor passing through a magnetic field depends upon three factors:

The strength of the magnetic field; the number of turns in the conductor cutting across the magnetic field; and the speed of rotation of the coil.

All constructional features in the design of generators provide for a balanced relationship among these three factors.

2. GENERATOR CONSTRUCTION

A generator consists of an outer ring of iron, called the yoke; a cylinder of soft iron

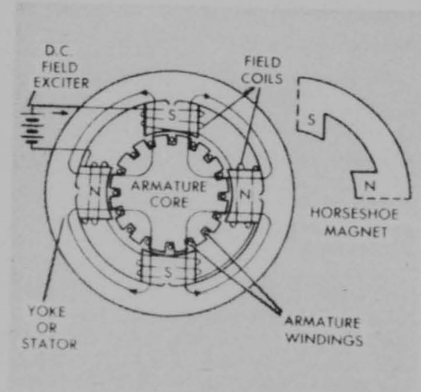

Figure 5—34. DC Generator.

with imbedded coils, called the armature; and a set of collector rings, or commutator segments, with collecting brushes to collect the current. The pole pieces project from the yoke and the field coils are wound on these pole pieces in such a way as to make them alternately north and south poles. The magnetic field, due to the alternate spacing of the poles, divides equally at each pole and, therefore, forms a resultant field made up of the same number of horseshoe magnets as the number

of poles, see Figure 5-34. There must always be an even number of pole pieces.

By winding the field coils on the pole pieces, the permanent magnets are changed into electromagnets, thereby greatly increasing the field strength without increasing the size of the pole pieces. By projecting the pole pieces from the yoke to form horseshoe magnets, the air gap in the magnetic circuit is decreased to the minimum clearance necessary for the rotation of the armature. As air offers much more reluctance to the magnetic field than iron, the air gap should be as small as the mechanical considerations will allow.

The armature consists of the armature coils, core, and collector rings or a commutator. Since the iron core acts as an iron conductor in a magnetic field, it is laminated to prevent the circulation of eddy current. The armature coils are made up of many turns of copper wire. As the number of turns in the loop are a factor in the amount of voltage generated, the greater the number of turns (limited by the increased resistance and dimensions of the machine), the higher the induced EMF will be. The copper coils, because of the weight and centrifugal force acting upon them during rotation, must be supported by the iron core. For mechanical safety and efficiency, the coils are set in slots cut in the core surface and wedged in place with wooden or fibre wedges for strength and support.

Finally, the EMF of the machine as a generator depends upon the speed. High speeds tend to cause mechanical failure because of the centrifugal force, hence speed is limited for safety considerations. If the coil has to move only half as far to cut the same number of lines of force, the speed might be cut in half and the same EMF or power be developed. The insertion of another pair of poles in the generator would have this effect. Many generators are multipolar, some of them with as many as 36 poles, to reduce the speed necessary for a given output. Addition of poles must be by pairs, with consideration of weight and space as the only limiting factor.

3. DC GENERATORS

The distinguishing structural characteristic of a DC generator is the commutator. The

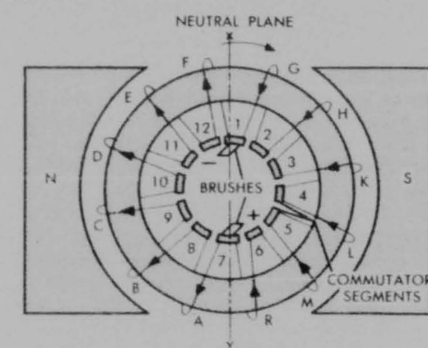

Figure 5—35. Commutators in DC Generator.

EMF and current in the armature coils of a DC machine are alternating the same as in an AC machine. It is by means of the commutator that the alternating EMF and current of the coils are collected as direct current for the external circuit.

The commutator consists of a number of wedge-shaped copper segments fitted together. The segments are insulated from each other by thin sheets of mica and the whole assembly is insulated from the shaft. A glance at the construction of the commutator reveals that mechanically it is the weakest part of the machine. Most of the electrical troubles originate at the commutator and brushes. The weakness of the commutator places a definite limit upon the safe speed of the rotation of the armature.

The two ends of each coil of the armature winding are mortised into, and soldered to adjacent commutator segments. Each commutator segment carries one terminal of each of two adjacent coils, one being the forward end of one coil and the other the rear end of the adjacent coil. Since each coil has two terminals and each commutator segment makes contact with two coils terminals, there must be as many commutator segments as there are coils. The illustration in Figure 5-35 will serve to make the statements clear. It is a schematic representation of a DC machine. For the sake of clarity in illustration, the coils have been shown as consisting of a single loop instead of the many turns of a full coil.

It is evident, upon examination of Figure 5-35 that the application of the left-hand rule shows the EMFs in the coils to be in a direction as indicated by the arrows. In both sides of the armature windings the EMFs induced in the coils are in a direction toward segment 1 and away from segment 7. Thus the two sides of the armature are in parallel, giving two paths for the current flow. The EMFs induced in the coils A, B, C, D, E, and F, being in the same direction and in series, are additive; and the total voltage of the generator is the sum of the voltages induced in the coils. The other six coils form a similar circuit and have a similar voltage, but being parallel the two voltages do not add, but act the same as cells in parallel. Therefore the voltage of a generator is the sum of the voltages in the coils in any one parallel path.

If the brushes are set upon segments 1 and 7, in the vertical plane represented by the dashed line, the upper brush will collect the current from the coils and is the positive terminal for the external circuit. The lower brush is the negative terminal, receiving current from the external circuit. That vertical plane (a plane perpendicular to the lines of force) which is midway between the poles is termed the neutral plane; for, when the coil passes through this plane, no EMF is induced. The neutral plane, then, is that plane in which no EMF is produced when cut by a conductor. The brushes in Figure 5-35, therefore, are set in the neutral plane, X and Y.

When a generator is delivering current to an external circuit, the current flow through the coils of the armature produces a magnetic field produced by the field coils. This effect is called the armature reaction of the generator. The neutral plane in Figure 5-35 was found to be also the vertical plane. This is true only when no current is flowing through the armature coils of a generator. As soon as current flows in the armature, the effect of armature reaction is to shift the neutral plane forward in the direction of rotation. This is one reason for the generator brushes not being actually set in the vertical plane as shown in Figure 5-35 but being set at some angle to the vertical.

The brushes of a DC generator are not set in the vertical plane, or in the shifted neutral plane. Instead, they are set just beyond the shifted neutral plane to prevent sparking between the brushes and the commutator. The armature coils are essentially highly inductive. Sparking in an inductive circuit occurs whenever current is flowing in the circuit and the circuit is broken. Before coil F, see Figure 5-35, reached the shifted neutral plane it is under the influence of the north pole and the direction of the current is as shown by the arrowhead. When commutator segment 1 and the commutator segment 12 are both in contact with the brush, coil F is short-circuited; a relatively heavy current flows through the circuit consisting of coil F, the two commutator segments 1 and 12, and the brush, until just after coil F passes through the shifted neutral plane. The size of this short-circuit current is reduced to a minimum in a DC generator by the use of carbon brushes, which have a higher resistance than metallic brushes. When commutator segment 1 leaves the brush, this short-circuit will be broken, and unless the current in coil F has been reduced to zero, a heavy sparking will occur at the trailing end of the brush. Therefore, the brushes are shifted so that commutator segment 1 leaves the brush just after coil F has come under the influence of the south pole of the generator. At this position, the current in coil F is reduced to zero because of the combined action of the self-inductance of the coil and the action of the south pole upon it, and sparking is at a minimum. In a 4-pole generator there are four positions in which a coil cuts no lines of force; hence, such a generator has two neutral planes at right angles to each other. Since two brushes are required for each neutral plane, the 4-pole generator has four brushes, two of which are positive and two of which are negative. The two positive brushes are strapped together as the two negative brushes are. There are four paths through the armature and the EMF of the generator is the sum of the EMFs in one-fourth of the windings.

It can be seen that although the EMF supplied to the external circuit is always in the same direction, it varies slightly in value from instant to instant, since the coil cuts the lines

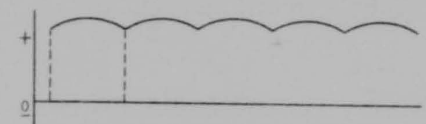

Figure 5—36. DC Generator Output.

of force at varying angles as it rotates through the field. This slight variation in value of the EMF taken from a DC generator is called ripple. The more coils in the winding of the armature, the smaller will be the ripple, as the number of lines cut by the increased number of coils will remain more constant. The EMF furnished to the external circuit by the generator of Figure 5-35 would have a waveform as shown in Figure 5-36.

DC generators are normally self-excited; that is, the current for the windings of the field magnets is taken from the commutator of the generator. This is possible because of the residual magnetism remaining in the cores of the electromagnets. When the machine is started, the armature starts turning in a weak field produced by the small amount of residual magnetism retained. The armature, in cutting this weak field, induces an EMF in the coils of the armature, and this induced EMF drives a current through the field coils which are connected in series or in parallel with the armature. The current increases the strength of the field magnets, thereby increasing the EMF induced in the armature coils, causing more current to flow through the field coil, again increasing the field strength, etc. It would appear that the EMF of the machine would continue indefinitely, building itself up to greater and greater values, but such is not the case. The maximum EMF of the machine is limited by the resistance of the field windings and the magnetization characteristics of the field magnets (saturation point).

Occasionally a DC generator that has the field coils reconnected will not build up its voltage. It may be that the residual magnetism is opposing the field from the field current. To remedy this condition, reverse the field connections.

4. TYPES OF DC GENERATORS

DC generators are generally known as shunt-series, or compound-wound generators. This designates the different types of generators in relation to the construction of their field windings. See Figure 5-37.

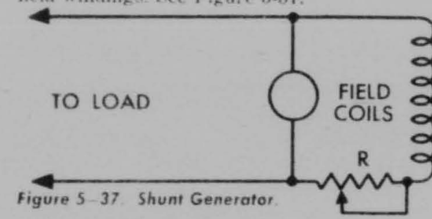

Figure 5—37. Shunt Generator.

The Shunt Generator

The shunt generator is so called because its field winding is connected in parallel (shunt) with the external circuit.

A schematic diagram of a shunt generator is shown in Figure 5-37. The field coils of a shunt generator are composed of many turns of small wire, and the magnetic strength is derived from the number of turns, rather than the current strength through the coils.

The shunt generator is suitable only for circuits requiring a steady flow of current at a steady voltage. It is not suitable for rapidly fluctuating loads if a constant voltage is required. Any increase in the current in the external circuit will cause an increase in the armature current. As the armature current increases, the IR drop through the armature is increased. The voltage delivered at the terminals is the difference between the induced voltage and the voltage drop. Thus, as the IR drop increases, the delivered voltage decreases. This decrease in voltage causes a decrease in the field strength, as the current through the field coils decreases in proportion to the decrease in terminal voltage; and with a weaker field, the voltage is further decreased, until a balance is reached.

Shunt generators are suitable for battery charging in a central office, and for similar application where the current drain is fairly steady. The voltage of a shunt generator may be controlled where necessary by the use of a rheostat in series with the shunt field.

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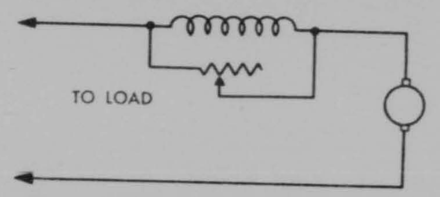

Figure 5–38. Series Generator.

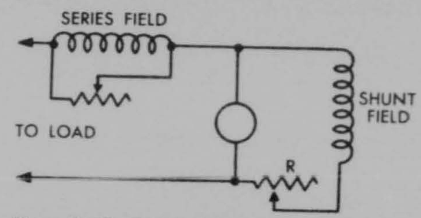

Figure 5–39. Compound Generator.

The Series Generator

The series generator, like the shunt generator, gets its name from the method used in connecting the field coils.

Figure 5-38 shows a schematic diagram of a series generator. The field coils of a series generator are composed of a few turns of large wire, and the magnetic field strength is derived from the current flow rather than the number of turns in the coils. The wire must be large since all of the current for the external circuit must pass through the coils.

Series generators have very poor voltage regulation under changing load; the greater the current through the field coils to the load, the greater will be the induced EMF and the increase in the terminal voltage of the generator. Therefore, when the load is increased the voltage will also increase. Because the series-wound generator has such poor regulation, it is seldom employed solely as a series machine; the series winding is used in other types of combination machine. The voltage of the series generator can, however, be controlled by a rheostat in parallel with the field coil.

The Compound-wound Generator

This generator is a combination of the shunt and series windings, and gets its name from this fact. The two separate windings are illustrated in Figure 5-39.

If the terminal voltage remains constant in a compound-wound generator, the ampere-turns of the shunt field are constant, but the ampere-turns of the series field vary directly with the current passing through them to the external circuit. Thus, the field strength increases and the EMF of the generator increases with an increasing load. If the series field contains the proper number of turns, the EMF of the generator may be made to rise sufficiently to compensate for the increasing drop of the potential in the armature IR drop. When the turns in the series field are just enough to keep the terminal voltage of the machine constant, the generator is said to be flat compounded. When the terminal voltage rises with an increase in load, the generator is over-compounded, and if the terminal voltage decreases with an increase in load, the generator is undercompounded.

In battery charging, it is often desired to change the rate of charge; therefore, some means must be designed to control the output of the generator. This is accomplished by placing a rheostat in series with the shunt field and a rheostat in parallel with the series field (see Figure 5-40). By a study of the circuit, it is noted that if rheostat 1 is varied, the current through the shunt field will vary, thus decreasing or increasing the voltage output of the generator. The same is true of rheostat 2, except that it controls the current through the series field by shunting a portion around the coils.

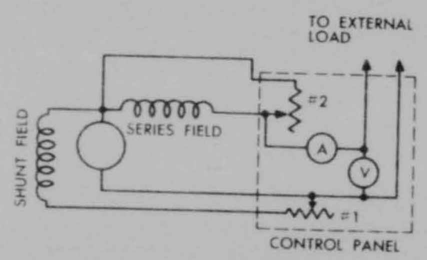

Figure 5–40. Generator Voltage Control.

SECTION VII—SHUNT, SERIES, AND COMPOUND MOTORS

1. MOTOR PRINCIPLES

Motors, like generators, are simply a means of transforming energy or power. Motors convert electrical power into mechanical power. The essential features and parts of all motors and generators are the same, and all DC motors may be used as generators. The DC motor has field coils, armature coils, and a commutator with brushes, the same as the essential parts of a generator.

To understand the torque (or turning effect) that is developed by a motor, an analysis should be made of a single-loop armature, mounted between the pole pieces of a permanent magnet. A cross-section of the conductors of such an armature is shown in Figure 5-41.

The field produced by a permanent magnet, in the absence of any disturbing force, travels the shortest route, which is directly across the conductors from the north pole to the south pole. If current is sent through the conductors of the loop, a field is set up around each conductor in a direction as determined by the left hand rule. These fields, due to current flow in the conductors, distort the main field and cause a piling-up, or flux pressure, on one side of each conductor and a flux vacuum on the other side. This causes a force to act upon the conductors which tends to push them into the vacuum, and to straighten out the distorted lines of force. If the field lines of force are thought of as rubber bands, and the conductors as some object pressing upon them, the effect upon the conductor may be understood more clearly. See Figure 5-42.

To determine the direction of rotation of a motor, the right hand is used, the method being known as the right-hand rule. This rule is similar to the left-hand rule for generators, except that the right hand is now used.

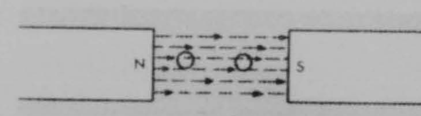

Figure 5–41. Conductors in a Magnetic Field.

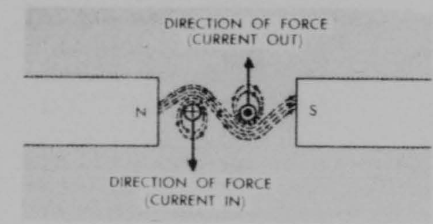

Figure 5–42. Motor Action.

2. SHUNT MOTOR

The shunt motor is structurally the same as the shunt generator and its schematic diagram is drawn in the same manner.

Since the field coils are always connected directly across the power supply, the current through the field will be constant. Therefore, the magnetic field will be constant and the torque of the shunt motor will vary only with the current through the armature. (The amount of torque depends upon the relative coupling between the fields set up by the armature coils and the field coils. The greater this coupling, the greater the torque.) With the armature coils rotating in a magnetic field, there is also an EMF induced. Thus, there is motor and generator action at the same time. This EMF induced will be in such a direction as to oppose the applied EMF, therefore it is a CEMF.

The amount of current which flows through the armature will depend upon the resistance of the armature and the difference between the applied voltage and the CEMF. The CEMF depends upon the speed with which the flux lines are cut, and since the armature coils are fixed to the armature core and the field does not vary, the CEMF depends solely upon the armature speed. The following formula is used for motor calculations:

$$\text{Armature current} = \frac{\text{E applied} - \text{CEMF}}{\text{RA}}$$

where R_A = armature resistance.

For example, suppose a motor develops a CEMF of 100 volts at 1,000 rpm, the armature resistance is 1 ohm and the applied voltage is 105 volts. Find the armature current at 1,000 rpm and 900 rpm.

CEMF = 100 volts at 1,000 rpm
RA = 1 ohm
E APPLIED = 105 volts

$$I_A = \frac{105 - 100}{1} = 5 \text{ amps at } 1{,}000 \text{ rpm.}$$

At 900 rpm, the lines cut will be 900 ÷ 1000 or 9/10 of the lines cut at 1,000 rpm, thus the CEMF will also be only 9/10 of that for 1,000 rpm, or 100 × 9 ÷ 10 equals 90 volts CEMF developed at 900 rpm. The current then would be:

$$IA = \frac{105 - 90}{1} = 15 \text{ amps at 900 rpm}$$

Since the CEMF developed is proportional to the speed of a motor, if a motor were at a standstill, and a voltage were applied to the motor terminals, there would be no CEMF to oppose this voltage, as the armature would not be cutting lines of force. Therefore, the current through the armature in the preceding example would be 105 amps, and this high surge of current occurs only on starting, and drops off as motor gains speed.

The speed of a shunt motor is fairly constant under changing load. As the load is applied, the speed of the armature rotation decreases, thus decreasing the CEMF and increasing the current. This increase in current boosts the coupling between field and armature and hence increases the torque, causing the motor again to resume approximate running speed.

The speed of a shunt motor may be controlled by a rheostat in series with the armature, or a rheostat in series with the field winding, or both; the rheostat in series with the field is the most common method. Adding resistance in series with the armature reduces the armature current, consequently lessening the torque and causing the motor to slow down until the current increases sufficiently to give the required torque. Adding resistance in series with the field winding reduces the field strength, decreasing the CEMF, thereby permitting more current to flow in the armature. The increased current speeds the motor due to the increased torque until the increasing CEMF reduces the current a sufficient amount to give the required torque. A rheostat in series with the field winding is preferable to a rheostat in series with the armature, because the field current is much smaller than the armature current and the power loss in the field rheostat will be much less than the power loss in an armature rheostat.

As the current flow through a motor armature is opposite to the current through a generator armature, the armature reaction tends to shift the neutral plane back of the vertical plane rather than forward as it did in the case of generators. Therefore, the brushes of a shunt motor are set back of the neutral plane instead of forward.

The shunt motor will operate only on direct current. The field and armature windings of this motor are in parallel, and the reactances of the two circuits when using alternating current are very different. This difference of reactance is due to the structural design of the two circuits. If alternating current were impressed across the shunt motor, the difference in reactance would cause the field current and the armature current to be out of phase and continuously changing phase. The operation of the motor would be unpredictable and the motor would be of little practical use.

3. SERIES MOTOR

The series motor may be operated on either alternating current or direct current, since the field is of low impedance and the same current flows through both the armature and the field. There can be no difference of phase between the field and armature in the series motor as in the shunt motor, because the field and armature current change direction together. If the motor is operated on direct current, the brushes are set back of the neutral plane to compensate for the armature reac-

tion. If the motor is operated on alternating current, the brushes are set in the vertical plane. The field cores must be laminated, if alternating current is used, to cut down the loss due to eddy currents.

The series motor is adapted for giving a very high starting torque. The torque of a series motor varies approximately as the square of the current. If the armature current is doubled, the flux is also doubled, since the same current passes through the field coils. Hence the torque, proportional to current x (flux) is increased four times. When the armature is at rest, the armature current (and therefore the torque) is at a maximum, because there is no CEMF generated in the coils and the current is equal to the impressed voltage divided by the resistance of the armature coils and the field coils. As the armature gains speed, the CEMF increases, thus decreasing the armature current and torque. If load is added to the armature, the armature slows down, decreasing the generated CEMF, allowing a greater current to flow, thus producing a greater torque. The speed of the series motor is controlled by the load, and if the load is removed, the motor will race dangerously. Series motors are therefore generally used only where the load is constantly applied and a good starting torque is required. Series motors are used in hoists, street cars, etc.

4. COMPOUND MOTOR

The compound motor, like the compound generator, has a combination of the series and shunt windings, and combines the separate characteristics of each. By making the field strength of one winding more powerful than that of the other winding, a compound-wound motor may be made to have the approximate characteristic of either a shunt or a series motor.

There are two types of compound windings: the cumulative compound, and the differential compound.

The Cumulative Compound

In the cumulative compound, the coils are wound upon the core in the same direction so that the magnetic fields tend to aid each other; from this fact comes the name cumulative-compound motor. A motor thus connected will have a very good starting torque, but poor speed regulation. Motors of this type are used for machinery where speed regulation is not necessary but where great torque is desired to overcome sudden application of heavy loads.

The Differential-compound Motor

The differential-compound motor has its windings wound in opposite direction so that the series-field winding oppose the shunt-field winding. A motor of this type may be made to operate at almost constant speed under varying load. As the load increases and the motor tends to slow down, the current in the series-field winding increases because of the decrease in CEMF.

The shunt-field winding draws a constant current as it is connected directly across the line. Since the series winding opposes the shunt winding, this increase in current through the series field will reduce the strength of the combined field. A decrease in the combined field will cause the motor to speed. If the number of turns on the series winding is properly chosen, the combined effects of the increased load and weakened resultant field neutralize each other and the speed will remain constant.

5. SUMMARY OF CHARACTERISTICS

The characteristics of motors may be classified as follows:

Shunt

A shunt motor has constant speed, fairly good speed regulation, speed control through variation of field resistance, good starting torque, and a tendency to run away if the field is open and it operates on direct current only.

Series

A series motor has speed dependent entirely upon the load, and a very high starting torque. The speed is controlled by variations of the field resistance, and it operates on either alternating current or direct current.

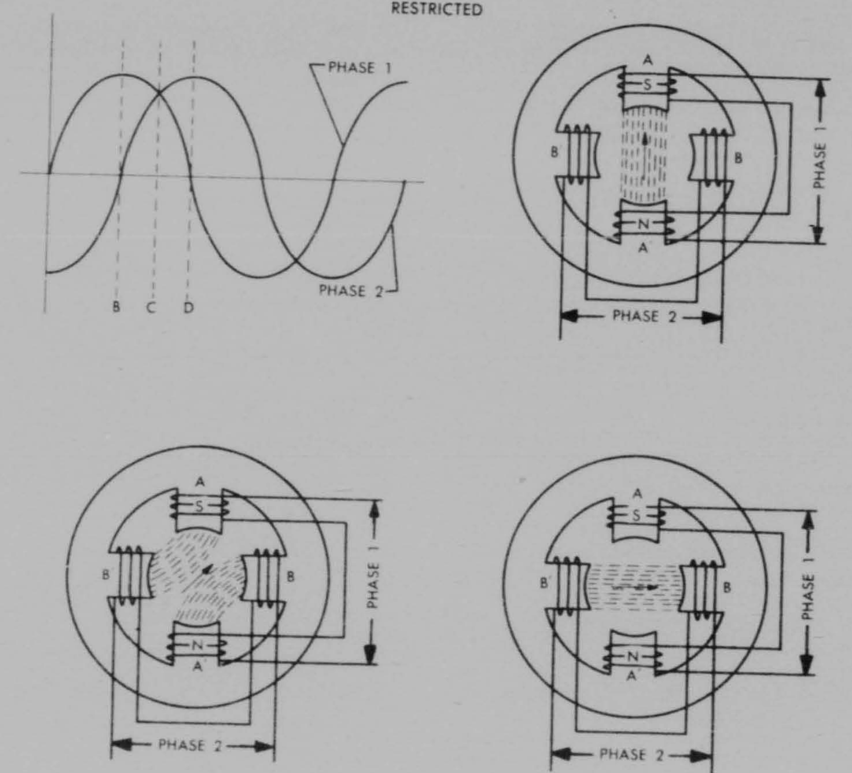

Figure 5–43. Production of Rotating Field.

Compound

A compound motor has speed which may be uniform throughout a wide range of load, speed control through variation of the field resistance, and good torque.

6. INDUCTION, SYNCHRONOUS, AND REPULSION MOTORS

The motors studied thus far were primarily DC motors, although with modifications in design, certain of them, notably the series motors, may be adapted to use on alternating current. The induction and repulsion motors now being covered are operated exclusively on alternating current.

Note: Thus far the discussion of alternating current has been limited to single phase alternating current, since this is the simplest method by which the student can acquire a conception of the AC principles and the quantities encountered in AC circuits. However, when AC power in large amounts is required, the general practice is to use multiphase alternating current, that is, more than one phase. Two-phase and three-phase systems are most common. It is possible to construct AC generators which will produce more than one EMF wave simultaneously, and at the same time maintain a constant phase relationship among them. In a two-phase system, for example, the phase angle between the two EMFs is 90 degrees, while in a three-phase system the angle is 120 degrees. Another way of stating the same facts is to say that in a two-phase system the two EMFs reach their maximum

values 90 degrees apart, while in a three-phase system, they reach their maximum values 120 degrees apart. The explanation of multiphase AC operation which follows is intended for purposes of reference only.

Principles of Multi-phase AC Motors

Multiphase AC motors depend for their operation upon the principle of a rotating magnetic field. As a simple illustration of the principles of a rotating magnetic field imagine a horseshoe magnet held over a compass needle. The needle will immediately take up a position parallel with the magnetic flux passing from one pole of the magnet to the other. If the magnet is rotated the compass needle will follow.

A rotating magnetic field can be produced by multiphase currents flowing through two or more groups of coils wound on inwardly projecting poles of an iron yoke. The coils on each group of poles are wound alternately in opposite directions to produce opposite polarity, and each group is connected to a separate phase of a multiphase EMF. This action will be explained with the aid of Figure 5-44, which shows a 4-pole field stator energized by two windings connected separately to the two phases of a two-phase generator. The direction of the magnetic field will be indicated by a magnetic needle (considered as a north pole only for convenience) which will always move to a position where it will be parallel with the magnetic flux passing from pole to pole and attracted to the resulting south pole.

Figure 5-43 illustrates the phase relationship of the two EMFs which are applied to the two windings of the field, phase 1 supplying current to the coils on poles A and A', and phase 2 supplying current to the coils on poles B and B'. The two EMFs are 90° out of phase with phase 1 leading. (1) At instant b (Figure 5-43), the current of phase 1 is at a maximum. The poles of coils A and A' are fully magnetized while the poles of coils B and B' are not magnetized, since the current in phase 2 is zero at this instant. Consequently, the magnetic needle will assume the position shown. (2) At instant c (Figure 5-43), the current in the coils A and A', phase 1, has decreased to the same value as that to which the current in coils B and B', phase 2, has increased. The four poles are now equally magnetized, concentrating the strength of the field midway between the poles and causing the needle to take the position shown. (3) The next instant, d (Figure 5-43), the current of phase 1 is zero and coils A and A' have no magnetism, while the current through coils B and B' is at a maximum; hence, the field strength is at a maximum and the needle is now in a horizontal position. (4) The above action is repeated during successive instants of the flow of the alternating currents, and the needle continues to revolve in the same direction within the field frame as long as the two-phase currents are supplied to the two sets of coils. If the compass needle is replaced by an iron core wound with copper conductors, secondary currents will be induced in these conductors producing a magnetic field which will react on the rotating magnetic field and cause rotation of the iron core. The direction of rotation may be reversed by changing the connections of one of the phases.

Induction Motor

The multiphase induction motor, has two elements; the fixed element or stator, and the movable element or rotor. However, the rotor of the induction motor is not energized from an external source. Briefly, the operation is as follows: A multiphase AC source of EMF is applied to the stator windings, producing a rotating magnetic field of force which cuts the conductors of the rotor, thereby inducing an EMF in them. The conductors form a closed circuit and the induced EMF therefore causes a flow of current. The interaction between this current and the air-gap flux causes the rotor to turn.

The speed of the induction motor is always less than the speed of the rotating field of the stator. If the rotor were to turn at the same speed as the rotating field, the rotor conductors would not be cut by any magnetic lines of force; no EMF would be induced in them, no current could flow, and with no current flow there could be no interaction with the air-gap flux and hence no torque.

A multiphase induction motor exerts a torque when at rest; therefore, it will start

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itself when the proper EMF is impressed on the stator. Small induction motors may be connected directly across the source of EMF. Starting compensators or some other means of reducing the starting current to a reasonable value are generally used with large-sized induction motors.

In addition to the multiphase induction motors just described, there are also single-phase induction motors. These machines have no rotating magnetic field and therefore no starting torque. Starting is accomplished, generally, by either one of two means: as a repulsion-start induction motor, in which case the machine starts as a repulsion motor and upon reaching a certain predetermined speed functions as an induction motor; or, as a split-phase induction motor in which case there are actually two windings, one of greater reactance than the other. The fields of these two windings will be sufficiently out of phase so that the resultant field will approximate a rotating field and produce a starting torque. When the motor has attained a certain speed, the second winding is disconnected and the machine will function as a single-phase induction motor.

The induction motor may be adopted to a greater variety of uses than any other type of AC motor. Its operating characteristics are good, it is simple and rugged in construction, and it requires a minimum of maintenance.

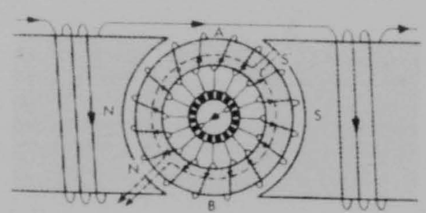


Figure 5-44 AC Repulsion Motor

Repulsion Motor

The repulsion motor, in its construction, may be thought of as a combination of an AC and a DC motor. Its stator is similar to that of a single-phase induction motor and its rotor like that of a DC motor. It is provided with brushes which are short-circuited. The operation of the repulsion motor may be described with the aid of Figure 5-44.

The magnetic field of the stator is assumed to be increasing in the direction shown. This field induces an EMF in the armature conductors and causes a current to be set up in the direction shown by the arrowheads. By placing the brushes at the angle shown, the current in the armature conductors will produce a magnetic field about the armature which will have definite N and S poles. These poles are repelled by the poles of the stator field, causing the motor to rotate in a counterclockwise direction. It is also from this fact that the motor derives its name.

The repulsion motor principle finds its greatest application when used to provide starting torque for single-phase induction motors.

7. SUMMARY OF MOTOR CHARACTERISTICS

The characteristics of the various types of AC motors described in the present lesson may be summarized as follows:

Induction Motor

The induction motor has reasonably constant speed, simple and rugged construction, and a wide variety of sizes. It requires a minimum of maintenance. The multiphase motor has good starting torque; the single-phase motor requires special measures for starting.

Repulsion Motor

The repulsion motor has good starting torque, and its principal application is in the starting of single-phase induction motors.

8. MAINTENANCE

The care and maintenance of motors and generators is a subject which cannot be emphasized too strongly. Any piece of moving machinery in order to function as its designer intended, must receive the proper care and treatment peculiar to that particular machine. However, it is not within the scope of this section to include anything more than a brief discussion of the general precautions

which should be observed for the proper operation of motors and generators. Specific instructions are generally published by the manufacturer or may be obtained from training manuals.

Bearings

The bearings of the machine should be lubricated with the proper grade of oil. The frequency of lubrication will depend upon the particular machine in question and the size of the oil reservoir associated with each bearing.

Commutator

The surface of the commutator should always present a bright, clean appearance. A clean, lint-free cloth should be used to maintain this condition. The commutator should never be oiled, although a small amount of vaseline may be applied after cleaning. The surface of a commutator may become rough and when this occurs, steps should be taken to restore the original condition. Minor surface irregularities may be removed with a piece of sandpaper, backed with a wooden block, held against the commutator. Emery or emery cloth should never be used. If the surface irregularities are of a more severe nature, the armature should be removed and the commutator turned down with a lathe. A common cause of surface irregularities is high mica, a condition resulting from the copper segments wearing away at a faster rate than the mica insulation between them.

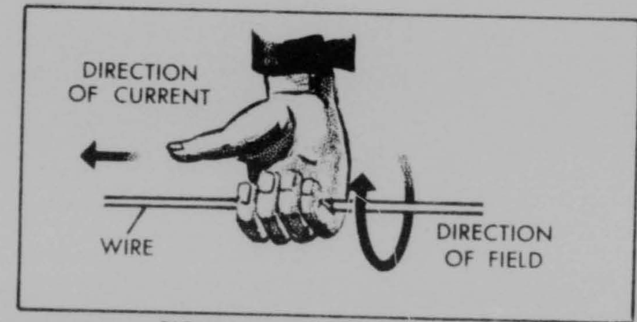
Brushes

Brush tension should be such that they make firm, but not tight contact with the commutator, and do not chatter or heat unduly. Excessive sparking at the brushes is undesirable and frequently is the result of incorrect brush position. In addition to incorrect brush position, sparking may be due to overload, rough or dirty commutator, high mica, improper brush tension, short circuited or grounded armature coil, or weak field excitation. The remedial measures to be applied are obvious.

Trouble Indicators

The temperature of a motor or generator provides a very accurate indication of whether or not the machine is operating properly. High temperatures indicate trouble. A good rule-of-thumb is that a temperature which cannot be borne by the hand is too high for safety.

The sound of a motor or generator, next to the temperature, is the best trouble indicator. When operating properly it should hum steadily. If it is overloaded it will "grunt." A knocking sound generally indicates a loose armature coil, the shaft out of alignment, or the armature striking a pole piece.



RIGHT-HAND THUMB RULE

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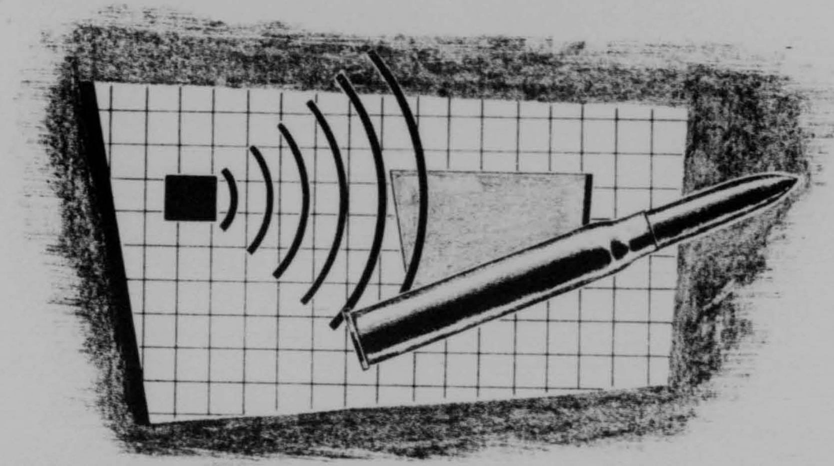
CHAPTER 6—EXPLOSIVES, AMMUNITION AND BALLISTICS



SECTION I—EXPLOSIVES

1. MILITARY EXPLOSIVES

General

To understand the composition and functioning of a complete round of ammunition, a basic knowledge of the characteristics and uses of military explosives is necessary. In order that ammunition may function at any time and place desired, it is necessary to employ different kinds of explosives, each having a specific role. Explosives suitable for one purpose may be entirely unsatisfactory for another. Thus, the explosive used to burst a forged steel projectile would not only be unsuited but also highly dangerous if used to propel the projectile out of the weapon. Similarly, the explosives used in initiators, such as in primers and fuses, are so sensitive to shock that only small quantities can be used safely.

Definition

Any mixture or compound which, under the influence of heat or mechanical action, undergoes a sudden chemical change (decomposition) with the liberation of heat and light energy accompanied by a large volume of gases, is called an explosive.

Classification

Explosives are classified as low and high explosives according to their rates of decomposition when such decomposition is initiated by the spit of a flame or mechanical shock. Therefore, explosives are divided into two basic groups: low explosives (propellants) and high explosives.

Low Explosives. Low explosives are combustible materials which decompose very rapidly; this action is called deflagration. In decomposition, they produce a large volume of gases which, in turn, produce enough pressure to propel a projectile or rocket forward. The rate of burning is important and depends upon such factors as pressure, grain form,

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composition, etc. Low explosives do not usually propagate a detonation. Under certain conditions, however, they react in the same manner as high explosives, that is, they may detonate.

High Explosives. High explosives are characterized by the extreme rapidity with which the decomposition occurs; this action is called detonation. They decompose almost instantaneously, either in a manner similar to an extremely rapid combustion, or with rupture and rearrangement of the molecules themselves. The disruptive effect of the reaction makes the explosive valuable as a bursting charge. However, it precludes its use as a propellant because the gases are formed so quickly that excessive pressures would be developed which might burst the barrel of the weapon. A detonation may be pictured as resulting from an explosion wave traveling through the high-explosive charge at an extremely high velocity.

Requirements of an Explosive

When the entire field of explosives is considered, the term "military high explosives" has a restricted application to a relatively small number of substances. Before an explosive can be adopted for military use, careful consideration must be given to its various properties and characteristics. The chief characteristics to be considered are stability, brisance, sensitivity, economy of manufacture and the explosive susceptibility to complete ignition or detonation.

Specific Military Requirements

If an explosive is to meet military requirements all the aforementioned characteristics must come up to specified standards.

Stability. Stability refers to the capacity of an explosive to retain unaltered its chemical and physical properties during an indefinite period of storage under normal conditions or at higher than normal temperatures. It also embraces the explosive's ability to withstand the mechanical shocks incident to loading, transportation and handling; its ability to withstand the shock of set-back on the firing weapon (when used in artillery shell), or impact when dropped "safe" (when used in bombs).

Sensitivity to shock or impact. Sensitivity to shock or impact refers to the ease with which an explosive can be detonated by the sudden application of mechanical force.

Sensitivity to detonation by means of initiators. The standard sensitivity to detonation by initiating agents other than mechanical impact is expressed in terms of the amount of initiating explosive; for example, the amount of mercury fulminate required to effect complete detonation of a given weight of explosive under a given set of conditions.

Brisance. Brisance is the ability of a detonating explosive to shatter material close to it. This property is different from the potential heat energy of the explosive, sometimes referred to as power or strength, which determines the force an explosive can exert when it explodes. Such force depends upon the amount of gas generated and the temperature reached during an explosion. Brisance, on the other hand, depends on the velocity with which a detonation occurs. Black powder, for instance, is a "powerful" explosive because of the large amount of gas it generates upon explosion. Its brisance, however, is very low because of the low rate of explosion.

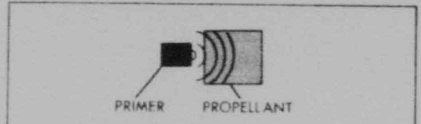

Figure 6–1. Simple Explosive Train.

2. EXPLOSIVE TRAINS

General

The arrangement of a series of explosives beginning with a small quantity of sensitive explosive and terminating with a relatively large quantity of comparatively insensitive explosive is termed an "explosive train." In general there are two such trains—the propelling-charge explosive train (which is always a low-explosive train), and the bursting-charge explosive train (which may be either a high or low-explosive train). In all explosive ammunition one or both of these explosive trains will be found.

Small-arms Ammunition. In small-arms

cartridges where the propelling charge is relatively small, the components in this train are a percussion primer and a propelling charge. The firing pin explodes the primer and the flame passes through the vent leading to the powder chamber and ignites the propelling charge. The expansion of the resultant gases forces the bullet out through the bore of the weapon.

Bursting-charge Explosive Trains. Although there are two explosive trains—the propelling-charge explosive train and the bursting-charge explosive train, the term "explosive train" as commonly used is intended to mean the bursting-charge explosive train. Bursting-charge explosive trains may be classified as high-explosive trains or low-explosive trains.

Low-explosive Train. When low-explosive projectiles or other types of missiles reach the point of functioning, the series of explosions which takes place is known as the low-explosive train. In base-ejection smoke shells, the explosive train consists of a percussion primer, a time train of black powder, a magazine charge of black powder, and an expelling charge of black powder. The action is initiated by the firing pin of the fuse striking the primer, the resultant flame being transmitted through the component next to the expelling charge. The explosion of the expelling charge forces the smoke canisters out of the base of the projectile.

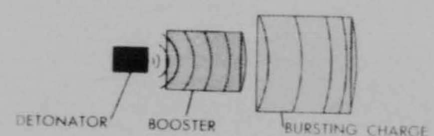

Figure 6–2. High-Explosive Train.

High-explosive Train. When the bomb reaches the target or the point at which it is set to function, the series of explosions which take place in order to detonate the bomb is known as the high-explosive train. The basic components which must be present in practically all high-explosive trains are a detonator, a booster, and a bursting charge. Other elements are sometimes required, but these three charges are fundamental.

The detonator sets up a high-explosive wave when initiated by the stab action of a firing pin or by a flame. This detonation is so small and weak that it will not initiate a high-order detonation in the bursting charge unless a booster is placed between the two. The booster picks up the small-explosive wave from the detonator and amplifies it to such an extent that the bursting charge is initiated with a high-order detonation.

To gain the action necessary to control the time and place at which an explosive will function, it is necessary to incorporate other components in the high-explosive train. The action desired may be a burst in the air, a burst instantly upon impact with the target, or a burst shortly after the bomb has penetrated the target. The components which may be used to give these various actions are a primer, a black-powder delay pellet or train, an upper detonator, or any combination of these components.

The action which causes a bomb to burst in the air may be obtained by placing a clockwork type device in the fuse to release the firing pin that initiates the explosive train a given number of seconds after the bomb leaves the aircraft.

To burst the bomb promptly upon impact with the target, a superquick or instantaneous action is necessary. This action is usually obtained by placing an upper detonator in the extreme front of the fuse and a lower detonator in the body near the booster charge. In this manner, the detonating wave is transmitted instantly to the bursting charge.

To permit penetration of the target by the bomb, a delay action is necessary. This is obtained by placing a primer and delay element ahead of the detonator.

A variation of the high-explosive train is found in the chemical shell. In this train there is no large bursting charge such as is found in a high-explosive bomb, as it is only necessary to rupture the bomb case and allow the chemical contents to escape. The actual bursting of the case is accomplished by an enlarged booster, known as a burster charge contained in a tube running down the center of the bomb.

3. PROPELLANTS

General

All explosives currently used as propellants have a nitrocellulose base and are commonly known as smokeless powders. Various organic and inorganic substances are added to the nitrocellulose base during manufacture to give improved qualities for special purposes. These powders are distinguished by such terms as double-base, flashless, and smokeless, as well as by commercial trade names or symbols. Black powder, which was formerly classed as a propellant, is no longer used as such but is now used as a delay element, as an igniting charge for propellants, in flash reducers, or for other special purposes.

Smokeless Powder

Characteristics. Smokeless powder is essentially gelatinized nitrocellulose and is manufactured in the form of flakes, strips, pellets, or perforated cylindrical grains. Powder is made in different shapes to obtain certain types of burning. The cylindrical grains are made in various diameters and lengths. Grains vary in diameter from 0.032 inch for cal. 30 cartridges to 0.947 inch for 16-inch propelling charges; they also vary in corresponding lengths from 0.085 inch to 2.170 inches. For small-size grains either no perforation or a single perforation is required. However, for larger grains, seven equally-spaced perforations are present in order to have a large-burning surface area. The critical dimension is the web size, that is, the average thickness of the powder between the perforations. In color, the grains vary from a light amber to a deep brown or black.

Solvent. Smokeless powder is manufactured to contain in the finished grains a definite amount of solvent (an ether and alcohol mixture). This amount varies from 0.5 to 5 per cent. If there is a marked change in the amount of solvent, a change in ballistic properties will result. Powder must be carefully protected against high temperatures and moisture. To guard against changes due to such conditions, smokeless powder is always packed in airtight containers. Some rocket propellent powder may not contain any solvent.

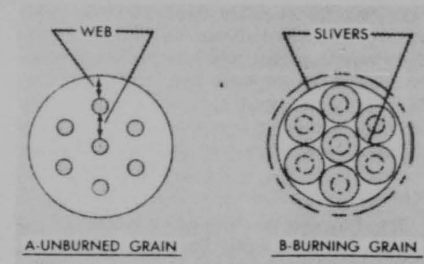

Figure 6–3. Progressive Burning of Powder Grains.

Burning Action

General. Unconfirmed smokeless powder burns with little ash or smoke but, when confined, its rate of burning increases with temperature and pressure. In order not to exceed the permissible chamber pressure of the weapon in which it is to be used, the rate of burning of the propellent has to be controlled. At constant pressure, the rate of burning is proportional to the powder surface free to burn. Therefore, powder is made into accurate sizes and definite shapes. Figure 6-3 illustrates the "progressive" burning of a powder grain.

Degressive Burning. As the surface of the cord and strip forms of smokeless powder change with burning, the surface of the grain decreases. The burning action of these grains is, therefore, classified as "degressive."

Neutral Burning. As a single-perforated grain burns, the outer surface decreases and the inner surface increases. The result of the two actions is that the total surface remains approximately the same in area. The burning of this type of grain is known as "neutral."

Progressive Burning. When the multiperforated grain burns, the total surface area increases since the perforated grain burns from the inside and outside at the same time. This type of burning is called "progressive" (Figure 6-3).

Slivers. When a multiperforated grain is not completely consumed, portions of the grain remain in the form of slivers B (Figure 6-3) and are normally ejected as such from the weapon.

Use. Nitrocellulose smokeless propellants are used as the propellant for small-arms and larger-caliber ammunition. The perforated form of grain is the one most commonly used in United States military powders. Single perforated grains are used for small-arms, minor-caliber weapons, and certain howitzers. Powders with seven perforations are used for larger-caliber weapons.

Double-base Powder (Ballistite)

Ballistite is a combination of nitroglycerin and nitrocellulose, containing approximately 13.15 to 13.25 per cent nitrogen obtained by mixing pyro powder (12.6 per cent nitrogen) with guncotton (13.35 to 13.4 per cent nitrogen). The nitroglycerin serves to increase the potential. Small percentages of inorganic salts are often added to reduce the flash and increase the ease of ignition. Ballistite is used in shotgun shells, field mortar increments, and rocket motors. Double-base powders cause more erosion in the weapon barrel but are being used increasingly because of the higher muzzle velocities obtainable by their use.

Standard Smokeless and Flashless Powders

These powders, which were formerly designated as FNH (flashless-nonhygroscopic) and NH (nonhygroscopic), are a mixture of nitrocellulose and other materials added to cool the products of combustion, thereby reducing the flash and the hygroscopicity, that is, the tendency to absorb moisture. They are used as propellants for most weapons of 37-mm and larger caliber. Nitroglycerin is used in certain powders where especially rapid burning is required and in certain high-velocity rounds and weapons.

Rounds of certain caliber, such as 3-inch, 76-mm, and 90-mm, are designated as "flashless," "smokeless," or "flashless-smokeless," depending upon flash and smoke characteristics upon firing.

Whether ammunition upon firing is flashless, smokeless, or both, depends upon the weapons in which used, the type of ignition used, weapon wear, the temperature of the tube of the weapon, and the quantity and design of the propellent powder. Flashless and smokeless are relative terms and have been defined as follows: flashless ammunition does not flash more than 5 per cent of the time in weapons of average life under standard conditions; smokeless ammunition produces less than half of the amount of smoke produced by ammunition not so designated. A complete round having both these characteristics is designated "flashless-smokeless."

Guncotton

Guncotton, a nitrocellulose of high nitration (13.35 to 13.4 per cent nitrogen) is used in the manufacture of propellents. It is also used in electric primers and in electrically initiated destructors.

EC Smokeless Powder

EC smokeless powder, or EC blank fire, consists of nitrocellulose with inorganic nitrates. It is usually orange or pink in color and resembles coarse sand, though it is soft and light. It is sensitive to friction, shock, or heat. It absorbs moisture readily and therefore must be protected from the atmosphere. It burns extremely rapidly in the open, but explodes if confined. It is usually exploded by flame from a primer or fuse. It was used at one time as a bursting charge in fragmentation hand grenades. It is used in cal. .30 and cal. .50 blank cartridges, in shotgun shells, and in cal. .22 ammunition.

Small-arms Propellants

Smokeless powder for small arms is usually glazed with graphite to facilitate machine loading and to prevent the accumulation of large charges of static electricity, and thus presents a black, polished appearance. Since the powder grains are small, they ignite more readily and burn more freely than cannon powder. When moisture is present or abnormal temperatures prevail, they are subject to more rapid deterioration than the larger grains. Many small-arms powders are nearly as sensitive to friction as black powder. Therefore, precautions used in handling black powder should be observed for small-arms powders. In general, there are two types of small-arms propellants, single-base and double-base.

A recent type of small-arms powder is in the form of small, spherical, graphite-coated balls and is used in carbine and cal. .45 ammunition.

Black Powder

General Characteristics. Black powder is an intimate mechanical mixture of finely-pulverized potassium nitrate or sodium nitrate, charcoal, and sulphur. The commercial blasting powder with sodium nitrate is now used for saluting purposes. Potassium nitrate is used in the powders for all other military purposes. Black powder is usually in the form of small, black grains which are polished by glazing with graphite. It is subject to rapid deterioration on absorption of moisture, but if kept dry it retains its explosive properties indefinitely. It is one of the most dangerous explosives to handle because it is very easily ignited by heat, friction, or spark.

Uses. In its several grades, its present military use is confined for the most part to:

Ignition and primer charges.

Expelling charges for base-ejection smoke shell, illuminating shell, and pyrotechnics.

Delay pellets for primers and fuses.

Blank ammunition charges.

Smoke-puff and spotting charges.

Precautions. Black powder is particularly sensitive to shock, friction, heat, flame, or spark. When black powder is handled in cans or bags or when it is not absolutely protected against sparks, special care must be taken.

4. HIGH EXPLOSIVES

General

High explosives are usually nitration products of organic substances, such as toluene, phenol, pentaerythritol, amines, glycerin, and starch, but may be nitrogen-containing inorganic substances or mixtures of both. Other materials, such as powdered aluminum, plasticizing oils, waxes, rubber, etc., may also be added to explosives to obtain desired characteristics.

A high explosive may be a pure compound or an intimate mixture of several ingredients. To avoid confusion in the writing of formulas of mixtures, the following order of listing of components, together with their proportions, has been decided upon: inorganic nitrates/explosives other than TNT/TNT/metals/inert materials. Within any of the preceding groups, the components are listed alphabetically should there be more than one of that particular classification.

Primer Mixtures

General. A primer mixture is an explosive sensitive to a blow such as that imparted by a firing pin. It is used to transmit shock or a flame to another explosive, a time element, or a detonator.

Composition. In a large number of mixtures, the primer mixture consists of mercury fulminate, potassium chlorate, and antimony sulfide, with or without ground glass and/or a binder. However, the chemicals and materials used may be altered, depending upon the type of action desired. Primarily, a primer mixture consists of an initiating high explosive, an oxygen carrier, and a combustible substance.

Uses. Primer mixtures are used in the percussion elements of cannon primers, in fuses, and in small-arms primers, and as the upper layer of a detonator assembly.

Mercury Fulminate

Characteristics. Mercury fulminate is a heavy crystalline solid, white when pure, but ordinarily having a faint brownish-yellow or grayish tint. It is extremely sensitive to heat, friction, spark, flame, or shock, detonating completely in nearly every instance. Its sensitivity varies with temperature. It has been found that its sensitivity is dependent in part on crystal size. It is nonhygroscopic and may be safely stored for long periods of time at moderate temperatures. However, it will not stand long-term storage at elevated temperatures.

Use. For all practical purposes, mercury fulminate has been replaced by lead azide. Its use is limited to small quantities in a few primers, in fuse detonators, and in blasting caps. It may be used alone or mixed with potassium chlorate.

Lead Azide

Lead azide is an initiating compound used to detonate high explosives. It is a fine-grained, cream-colored compound. It is sensitive to flame and impact but it is not certain to detonate by the action of a firing pin. It does not easily decompose during long, continued storage at moderately elevated temperatures. It flashes at a much higher temperature than mercury fulminate. A smaller weight of lead azide than of mercury fulminate is required to detonate an equal amount of TNT, tetryl, etc. Lead azide is replacing mercury fulminate because of its properties and because it stands up better in storage and is less hazardous to manufacture. It is found in primer mixtures and in detonator assemblies in fuses.

Tetryl

Characteristics. Tetryl (trinitrophenylnitramine) is a yellow, crystalline solid. When heated it first melts and then decomposes and explodes. It burns readily and is more easily detonated than TNT or ammonium picrate, being much more sensitive than picric acid. It is detonated by friction, shock, or spark. It is practically nonhygroscopic. Tetryl is stable at all temperatures which may be encountered in storage.

Detonation. Brisance tests show tetryl to have a very high shattering power. It is greater in brisance than picric acid or TNT and is exceeded only by PETN and some of the newer military explosives, such as RDX.

Use. Tetryl is used as a charge and as a detonator.

Charges. Tetryl is the standard booster explosive and is sufficiently insensitive when compressed to be used safely as a booster explosive. The violence of its detonation insures a high-order detonation of the bursting charge. It is used in the form of pressed pellets. Tetryl is the standard bursting charge for small-caliber (20-mm and 37-mm) projectiles. It produces appreciably better fragmentation of these shells than TNT. It is also more readily detonated and yet in small-caliber shell withstands the force of set-back in the weapon. It is also a component of tetrytol.

Detonator. Tetryl is used in detonators, the tetryl being pressed into the bottom of the detonator shell and then covered with a small priming charge of mercury fulminate, lead azide, or other initiator.

TNT (Trinitrotoluene)

General. Although trinitrotoluene was known as early as 1863, it was not suggested as an explosive until about 1890, and its importance from a military standpoint dates from 1904. Since that time, it has appeared as the principal constituent of many explosives, and has been used by itself under such various names as triton, trotyl, tolite, trilite, trinol, tritolo, etc. It is commonly known in this country by the abbreviation TNT. The term trinitrotoluol, which is more generally used than trinitrotoluene, is less correct from the chemical point of view than the latter.

Characteristics. TNT when properly purified is one of the most stable of high explosives and can be stored over long periods of time. It is relatively insensitive to blows or friction. Confined TNT, when detonated, explodes with violence. When ignited by a flame, unconfined TNT burns slowly without explosion evolving a heavy oily smoke; however, burning or rapid heating of large quantities, especially in closed vessels, may cause violent detonation. It is readily detonated by mercury fulminate, tetryl, and similar high explosives. It is nonhygroscopic and does not form sensitive compounds with metals, but is readily acted upon by alkalies to form unstable compounds which are very sensitive to heat and impact. It usually resembles a light brown sugar, but when pure is crystalline and is nearly white. Easily melted and poured into a shell or bomb to form a solid crystalline explosive charge, TNT is a very satisfactory military explosive. The melting point of standard Grade I TNT is 80.2°F.

Ammunition loaded with TNT can be stored, handled, and shipped with comparative safety. Both grades of TNT are slightly toxic, and it is necessary that proper precaution be taken by those engaged in its manufacture or handling to avoid inhaling the vapors or dust from the molten or crystalline material. Good ventilation in manufacturing or shell-loading plants is highly essential, and personal cleanliness should be enforced.

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Exudation. When stored in warm climates or during warm summer months, some ammunition loaded with TNT may exude an oily brown liquid. This exudate oozes out around the threads at the nose of the shell and may form a pool on the floor. The exudate is inflammable and may carry small particles of TNT. Pools of exudate should be removed.

Detonation. TNT in crystalline form can be detonated readily by a No. 6 blasting cap or when highly compressed by a No. 8 blasting cap. When cast, it is necessary to use a booster charge of pressed tetryl or an explosive of similar brisance to insure complete detonation.

Use. Bursting Charge. TNT is used as a bursting charge for high-explosive shells and bombs either alone or mixed with ammonium nitrate to form 50/50 or 80/20 amatol. Flake TNT is used in 37-mm shells and in fragmentation hand grenades. Other military uses of TNT are in mines and for parts of certain shell and bomb bursters.

Ammonium Picrate (Explosive D)

Characteristics. Ammonium picrate is the least sensitive of military explosives to shock and friction. This makes it well suited for use as a bursting charge in armor-piercing projectiles. It is slightly inferior in explosive strength to TNT. When heated, it does not melt but decomposes and explodes. It reacts slowly with metals, and when wet it may form sensitive and dangerous compounds with iron, copper, and lead. It is difficult to detonate but burns readily like tar or resin.

Special Precautions. Ammonium picrate, which has been pressed at a shell-loading plant and removed from a shell, is much more sensitive to shock or blow than fresh ammonium picrate. It should be protected against shock or fire and should preferably be stored alone in a building. Although less sensitive than TNT, it can be exploded by severe shock or friction, is highly inflammable, and may detonate when heated to a high temperature.

Use. Explosive D is used as a bursting charge for armor-piercing shell, in projectiles for seacoast cannon, and in other types of projectiles which must withstand severe shock and stresses before detonating.

Picratol

General. Picratol is a mixture of 52 per cent explosive D and 48 per cent TNT. It can be poured like straight TNT and has approximately the same resistance to shock as that of straight explosive D. The brisance of picratol is between that of explosive D and TNT. Picratol is nonhygroscopic.

Use. Picratol is a standard filler for all Army and semiarmor-piercing bombs.

Tritonal

Tritonal is a generic term for explosives containing TNT and aluminum, generally in the ratio of 80/20. It produces a greater blast effect than TNT or Composition B described below. It is used in light-case and general-purpose bombs.

RDX

RDX is also known as "cyclonite" (cyclotrimethylenetrinitramine), CTMTN, C6, hexogen (German), and T4 (Italian). It is a white crystalline solid having a melting point of 202° C. It has about the same power and brisance as PETN. It is more easily initiated by mercury fulminate than is tetryl. It has a high degree of stability in storage. RDX is never used alone but in mixtures with other explosives and or oils and waxes.

Torpex

Torpex is a gray compound consisting of RDX, TNT, aluminum powder, and beeswax (or similar wax). It is a more powerful but much more sensitive explosive than TNT. Torpex is nonhygroscopic, noncorrosive, and has a very high brisance. Under water it is 50 per cent more destructive than TNT, whereas in air the difference is approximately 30 per cent. Torpex is used as a bursting charge in mines, torpedoes, and depth charges.

Composition B

Composition B (Comp. B) is a mixture of RDX, TNT, and beeswax or similar wax. It is a nonplastic material which is cast-loaded. It is one of the most powerful explosives. It is less sensitive than tetryl but more sensitive ing for AN (Army-Navy) standard aircraft bombs, mines, and torpedoes, and may be used than TNT. Composition B is an authorized fill-in boosters for large bombs, demolition charges, and larger-caliber projectiles.

SECTION II—AMMUNITION

1. SMALL-ARMS AMMUNITION

Definitions

Small-arms ammunition is used in weapons having a bore inside of barrel of 0.60 inch or less in diameter. (Carbine—0.30 inch; Pistol—0.45 inch; Submachine Gun—0.45 inch; Machine Gun—0.50 inch.)

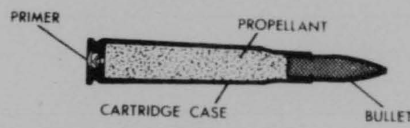

Figure 6—4. Complete Round.

Complete Cartridge (Round)—a complete unit consisting of all the parts necessary to fire the weapon once. The four major parts of a small-arms cartridge are the primer, propellent powder (propelling charge), bullet (projectile) and cartridge case. (Figure 6-4).

Primer. Located in the rear (head) of the cartridge, and used to set off the propellent powder. It consists of:

A cup—made of soft metal. (Figure 6-5).

A primer composition (primer mixture) made of a nonmercuric or noncorrosive explosive. Lead azide is usually used.

A disc—made of shellacked manila paper.

An anvil—made of brass.

The cup holds the primer composition (mixture) which is held in place and protected from moisture by the disk. The anvil fits over the disk in the cup. A blow from the firing pin (in the weapon) on the primer cup pinches the

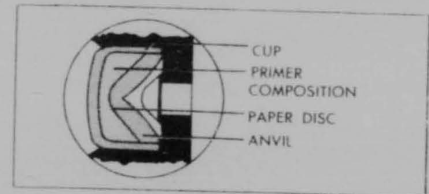

Figure 6—5. Primer Assembly.

primer composition between the cup and the anvil, thereby starting a flame.

Propellent Powder. Located within the cartridge case, consists of a quantity of smokeless powder which is a low explosive. The flame from the primer composition passes through the vents (passages) in the anvil and cartridge case and ignites the propellent powder. Expanding gases result from the burning of the powder creating pressure which propels (forces) the bullet out of the cartridge case, and through the barrel of the weapon.

Bullet. Located in the front (neck) of the cartridge case, and used to strike the target and cause the desired result. For example: wound, kill, set on fire, penetrate armor, etc. It consists of the following:

A jacket—made of gilding metal (90 per cent copper and 10 per cent zinc alloy), serves two purposes. One, the lands cut into the jacket and cause rotation of the bullet, giving it the necessary stability in flight. Two, it fits the bore tightly thus preventing the escape of gas past the bullet. The bore of a military weapon is always measured from the top of one land to the top of the opposing land. As an example, the cal. .50 is 50 hundredths of an inch (.50) from one land to the opposite land. The land depth is 5 thousandths (.005) of an inch. With the two lands the total is 10 thousandths (.010) of an inch, thereby giving a groove to groove measurement of 5 hundred and 10 thousandths (.510) of an inch. The bullet must then have 1 thousandth of an inch (.001) additional gilding metal added to its diameter, giving a total bullet diameter of .511 of an inch. The gas seal is now accomplished and the lands must cut into the jacket to give rotation to the bullet. (See Figure 6-6).

Core (filler of the bullet)—made of lead alloy, common steel or hardened steel alloy, tracer, or incendiary.

Point filler—lead, antimony-lead, or incendiary.

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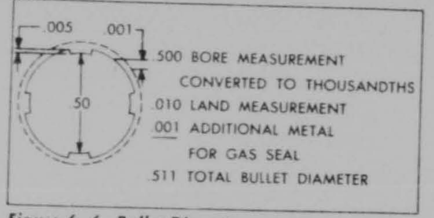

Figure 6–6. Bullet Diameter.

Base filler (base seal)—gilding metal, tracer composition, or some other filler.

Cannelure—the groove around the bullet—prevents the bullet from being pushed back into the cartridge case during automatic feeding of the weapon, and rough handling.

Ogive—streamlined portion at front of bullet.

Meplat—nose of the bullet. Tends to reduce ricochet. Does not prevent ricochet.

Conicle taper—(Boattail-type bullet only)—at the rear of the bullet.

Cartridge case is made of brass in most cases but may be made of steel. It has three functions: holds the other major components together as a unit, provides a waterproof container for the propellent powder, and when the cartridge is fired, it prevents the escape of gases to the rear by expansion of the thin side walls causing them to adhere to the walls of the chamber by the pressure. The component parts of the cartridge case are:

The mouth—opening for insertion of propellant and bullet.

The lip—edge of mouth to be crimped into the cannelure.

The neck—holds the bullet in place. A thin coat of varnish is applied inside the neck to waterproof the propellant.

Shoulder—the taper between the neck and the body. It must conform to the profile of the chamber.

Body—acts as a basis for the other component parts.

Wall—the average thickness of the brass in the body.

Head—the thickness of the brass at the base of the cartridge case that provides a place for the extracting groove, primer pocket and primer vent.

Primer pocket—a pocket punched in the head to hold the primer.

Primer vent—a passage punched from the primer pocket into the propellent cavity to allow the flame or spark of the primer mixture to ignite the propellant.

Extracting groove—the groove at the head of the cartridge case that allows the removal of the spent case from the chamber by a mechanical extractor.

Propellent cavity—inside of the case that holds the propellant. (See Figure 6-7).

The cartridge case is made from a circular disk of brass which is punched into the form of a cup. The cup is then drawn through dies until its proper shape is formed. The closed end is then pressed into shape. The manufacturer's initials and primer pocket are punched. The extracting groove is then machined.

There are annealing and washing processes between the draw and punching stages. The final case has a hard tough head to withstand the pull of extraction, and the side walls are soft but resilient (springy) enough to spring back after expansion. The mouth of the case is annealed to a dark bluish color to prevent season cracking. The cases then go to the pierce and prime process where the primer vent is punched and the primer is staked in place. The loading process is next. The case is loaded with a charge of propellent powder and the inside of the neck is coated with varnish or lacquer. The bullet is inserted and the lip is crimped into the cannelure. Cal. .30 carbine and cal. .45 cartridges are not crimped but held in place by the tight fit of the bullet.

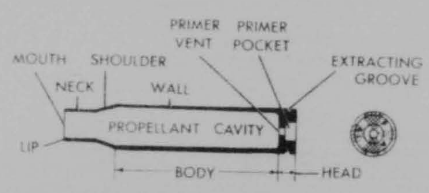

Figure 6–7. Cartridge Case.

Color of bullet tip	Type of cartridge
No Color	Ball
Black	Armor-piercing
Aluminum	Armor-piercing-incendiary
Red	Tracer Cal. .50 M1 M-21 Carbine M-16 Cal. .45 M-26
Maroon	Tracer Cal. .50 M17
Orange	Tracer Cal. .50 M10 Carbine M27
Red/w/aluminum color rear annulus	Armor-piercing - incendiary-tracer
Blue w/light blue rear annulus	Incendiary Cal. .50M23
Blue w/aluminum color rear annulus	Armor-piercing incendiary cal. .50T49
Green w/white rear annulus	Frangible

Classification

Small-arms ammunition is classified according to its purpose, as service (combat) or special-type ammunition.

Service-type ammunition. Ball—for use against personnel and light-material targets.

Tracer—for observation of fire. Secondary purposes are for incendiary and signaling.

Incendiary—to start fires, especially against aircraft.

Armor-piercing—used against armored aircraft.

Armor-piercing incendiary—for combined armor-piercing and incendiary effect.

Shot—used for hunting small game with the cal. .45 pistol (contains #7½ chilled shot).

Grenade—used for launching rifle grenades by means of a rifle or carbine equipped with a grenade launcher.

Special-type ammunition. Dummy—used for training purposes, such as loading and unloading of weapons (completely inert).

Blank—for firing salutes (no bullet).

High-pressure test—for use only in proof firing of weapons. Testing the strength of weapons.

Frangible—for target practice against specially-armored aircraft. The bullet disintegrates upon hitting the aircraft. The bullet is made of plastic and lead.

Identification of Ammunition Types

In general, all types of cartridges of one caliber have the same profile. They may be identified, except as to ammunition lot number and grade, by the physical characteristics that have been explained and by the color of the bullet tip. The colors of the various types are listed in the table below.

Range

The range of the various types of ammunition is listed below. Maximum range is the greatest distance the gun can fire, and the range of trace is the greatest distance the tracer color is visible.

Caliber .30 carbine	
Ball, M1, Max. Range	2,200 Yds
Tracer, M16, Max. Range	1,680 Yds
Max. Trace	570 Yds
Caliber .45 Pistol	
Ball, M1911, Max. Range	1,640 Yds
Shot, M12, and M15 - Not Given	
Tracer, M26, Max. Range	1,600 Yds
Max. Trace	260 Yds
Caliber .50 Machine Gun	
Ball, M2, Max. Range	7,275 Yds
AP M2, Max. Range	7,275 Yds
API M8, Max. Range	6,375 Yds
API T49, Max. Range	5,500 Yds
API-T M20, Max. Range	6,375 Yds
Max. Trace	1,800 Yds
Incandiary, M-1	
Max. Range	5,960 Yds
Tracer, M1, Max. Range	5,470 Yds
Max. Trace	1,800 Yds
Tracer, M10, Max. Range	5,350 Yds
Max. Trace Dim	150 Yds; Bright to 1900 yds.
Tracer, M17, Max. Range	5,350 Yds
Max. Trace	2,450 Yds
Tracer, M21, Max. Range	5,470 Yds
Max. Trace	550 Yds

Grades of Ammunition

Ammunition is manufactured to strict requirements, and is inspected and tested thoroughly before acceptance. Since the various types of weapons—carbines, pistols, machine guns, etc.—have different requirements, production orders and specifications call for the classification of lots of ammunition for use in specific weapons.

Differences in manufacture may occur because of problems of mass production of ammunition. Considering differences from lot to lot and the different requirements for each type of weapon, grades are assigned to each lot of ammunition, in accordance with inspections and acceptance tests, to designate their use in the different types of weapons.

Grades for cal. .30 carbine ammunition.
R—Carbines.
3—Unserviceable, not to be issued or used.

Grades for cal. .45 ammunition.
1—Revolvers, pistols and submachine guns.

2—Pistols and submachine guns only.
3—Unserviceable, not to be issued nor used.

Grades for cal. .50 ammunition.
AC—Aircraft and antiaircraft machine guns.
MG—Ground machine guns.
3—Unserviceable, not to be issued nor used.

When small-arms ammunition becomes unserviceable, it is graded as grade 3 and withdrawn from service. Ammunition which cannot be identified will be considered as grade 3. However, unidentified ammunition will not be classified as unserviceable until every effort has been made to establish its identity.

Current grades of all existing lots of small-arms ammunition are made by the Chief of Ordnance as a result of inspection, and are published in SB 9-Ammo 4.

Ammunition Lot Number

Although small-arms ammunition is produced on a continuous, mass-production basis, a difference is made between the quantities of completed cartridges which contain identical component items or materials. For purposes of identity and accounting, each quantity of ammunition is identified by a lot number. Different blocks of lot numbers (in thousands) are assigned to each manufacturer. The manufacturer's initials are also designated as part of the ammunition lot number. (Examples are listed below.)

Denver Ordnance Plant	DEN
Des Moines Ordnance Plant	DM
Frankford Arsenal	FA
Remington Arms Company	RA or REM
St. Louis Ordnance Plant	SL
Utah Ordnance Plant	UT or U
Winchester Repeating Arms Co.	WRA

Each manufacturer is authorized to assign the same lot number to one lot of each type or each caliber manufactured at that plant. It is, therefore, essential that each ammunition lot be identified by its ammunition identification code (AIC) or its standard nomenclature, together with its lot number.

Ammunition Identification Code

An ammunition identification code (AIC) has been established to facilitate the supply of ammunition in the field. The AIC symbols are used for identifying ammunition items in messages, requisitions, and records. Once an AIC is assigned to any item of ammunition it will never be changed. The AIC always consists of five characters: the first, third, fourth, and fifth are capital letters; the second is an arabic numeral. In general, the following meanings are attached to these characters.

1st and 2d characters—the SNL in which the item is listed.

3rd character—the weapon or group of weapons.

4th character—the type and model of ammunition.

5th character—the kind or method of packing.

T1EDV is a typical AIC. The first two characters mean that this item of ammunition is listed in ORD 11 SNL T-1. Ammunition of different types (ball, AP, TR, etc.) having the same lot numbers must be accompanied by the AIC, and the fourth character of the AIC will show that the ammunition is of a different type. Example:

FA 8000	T1EDV	Ball ammunition
FA 8000	T1EEV	AP ammunition
FA 8000	T1EHV	Tracer ammunition

Packing

The containers and methods for packing small-arms ammunition are given in drawings, specifications, and standard nomenclature lists. Present containers have been reduced to a few standard types to withstand all conditions commonly encountered in handling, storing, and transporting the ammunition.

With few exceptions, small-arms ammunition is issued in metal containers packed for shipment in wooden boxes. There are two types of metal containers; hermetically sealed cans opened by means of a key and tear strip, and the metal boxes having hinged covers sealed by means of a rubber gasket. The first type is used for packing cal. .30 carbine, cal. .45 and some cal. .50 ammunition. The outer containers are either wooden packing boxes or wire bound crates.

Markings of packing containers. The outer containers are stained or painted dark brown

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(chocolate) with the stenciling or printing in yellow, or unstained with stenciling or printing in black. All metal containers are olive drab with markings in yellow.

Safety Precautions

Small-arms ammunition, as compared with other types of ammunition, is not dangerous to handle. Care, however, must be observed to protect the primers from being struck by any sharp instrument as such a blow might explode the cartridges.

Small-arms ammunition is not an explosive hazard in storage, although under adverse conditions it may become a fire hazard. It is advisable to keep personnel not engaged in fighting the fire at least two hundred yards distance and have them lie flat on the ground due to the hazard of flying bullets and cartridge cases.

Tracer ammunition should be stored separately from other ammunition if practicable.

The use of grease or oil on cartridges is prohibited. These agents cause injurious abrasives to collect in automatic weapons and produce excessive and hazardous pressures on the rifle bolts when non-automatic rifles are fired.

Ammunition should always be stored under cover when possible and kept well ventilated. If ammunition must be stored in the open, it should be stacked on dunnage at least six inches from the ground and be covered with a double thickness of serviceable tarpaulin.

Ammunition should not be opened until ready for use.

If an ammunition box is broken, the box should be repaired immediately. All markings should be transferred to the new part of the box.

2. 20-MM AMMUNITION

Major Component Parts

20-mm ammunition differs from small arms ammunition in that they have an additional component part. The high-explosive rounds have two additional component parts. The parts are as follows:

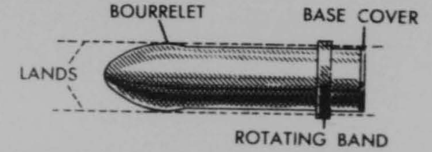

Figure 6–8. 20 MM Ammunition.

Cartridge case.
Propellant charge.
Primer.
Projectile.

Rotating Band (Figure 6-8). Located on the lower portion of the projectile. It is made of copper or gilding metal and has a slightly greater diameter than the raised part of the riflings. This allows the lands to cut into the metal and give rotation to the projectile to stabilize it in flight; it also prevents the gases from escaping past the projectile.

Fuse (with high explosive rounds only).

Bourrelet (Boor-Lay). A very accurately-machined portion on the forward part of the projectile that rides on top of the lands. It acts as a forward bearing surface and prevents the projectile from wobbling in the bore.

Base Cover. The base cover is used with the high-explosive round only. It is a metal disk that is electrically welded to the base of the projectile. Its purpose is to prevent premature explosions due to cracks or flaws in the metal.

Classification of 20-mm Ammunition

20-mm ammunition is classified according to the projectile used. The standard projectiles used are:

High Explosive Incendiary (HE-I). The projectile contains both a high-explosive and an incendiary mixture.

Incendiary (I). Projectile contains an incendiary mixture only.

Armor Piercing With Tracer. (Figure 6-9). The projectile is machined from cold-drawn bar steel. The radius of the ogive is rounded giving it a blunt appearance. A windshield or false ogive is added so that when the projectile strikes the target, the windshield folds back and acts as a guide to prevent ricocheting off the target. A cavity is machined into the back of the projectile to receive the tracer. The

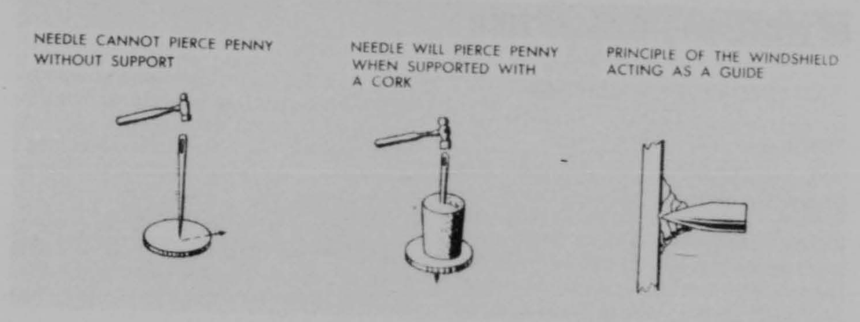

Figure 6–9. Principle of AP Ammunition.

tracer is ignited by the heat of the propellant.

Ball. The projectile is hollow in the center and is inert.

High Explosive–Incendiary Cartridge

The HE-I round is generally fired from aircraft guns against enemy aircraft, although it may be directed against light ground targets and personnel.

Complete Round. The complete round consists of all the major component parts necessary for a high-explosive round plus a high-explosive filler and an incendiary mixture which are located in the projectile.

Fuze. The fuze is classified as an instantaneous percussion fuze of the impact type which can go thru material and act on heavier material of the aircraft. The fuze has a primer of mercury fulminate, a detonator of lead azide, and a relay detonator of tetryl. The fuze is screwed into the projectile which has a bursting charge of tetryl and the incendiary mixture.

Identification of 20-mm Cartridges

20-mm cartridges is identified as follows:

HE-I. The fuze is brass. From the base of the fuze to the bourrelet is painted yellow. From the bourrelet to the rotating band is painted red with "Shell, HE-I 20-mm" and M (model number) painted in black. The rotating bands are never painted on any ammunition. The primary reason for painting artillery projectiles is to prevent rust and secondly to have a ready means of identifying them.

AP-T. The entire projectile is painted black with markings "Shot, AP, 20-mm" and M (model number) with tracer painted in white below the bourrelet.

Ball. The entire projectile is painted black. There are no markings.

Safety Precautions in Handling 20-mm Ammunition

The ammunition should be handled with care at all times. The explosive elements in the primer and fuzes are highly sensitive to shock and high temperature.

No attempt should be made to disassemble any fuze or complete round. This practice is prohibited.

Although the use of oil and grease is generally prohibited, it is necessary with 20-mm ammunition to prevent jamming. A light coat of oil is applied just prior to insertion in the magazine or belt. Extreme caution should be exercised to prevent the oil from saturating the primer or mouth of the cartridge case.

Dud ammunition is not to be handled. Dud ammunition is ammunition that has been fired and did not detonate. It will be disposed of by authorized and qualified personnel.

SECTION III—BALLISTICS

1. THE THEORY OF BALLISTICS

Definition

Certain characteristics of cartridges and particularly of their discharge in firearms are referred to as the "ballistics" of ammunition. The term ballistics comes to us through the original Greek root word, "balleiu" meaning to throw. It is defined as the science of motion of projectiles. It is a study of various forces, controllable and uncontrollable, which govern the movement of projectiles. Ballistics are divided into two branches, internal and external ballistics.

Internal ballistics of a cartridge are those functions that take place after firing the weapon, but before the projectile has left the muzzle end of the barrel. They include the chamber pressure expressed in pounds per square inch (Figure 6-11); the curve of pressure as the projectile progresses through the barrel, expressed by means of a graph; the free recoil of the weapon, expressed in foot pounds; the time of travel, expressed in thousandths of feet per second. (See Figure 6-10).

External ballistics describes the action of the projectile after it has left the muzzle end of the barrel, including the various affecting factors, which are: muzzle velocity expressed in feet per second, and is measured in the first second of flight, as the projectile leaves the muzzle end of the weapon. The remaining or average velocity is expressed on distance or a given range.

Trajectory is the path that the projectile takes, between the muzzle of the gun, and the point of impact. The path of the projectile is affected by the following factors (See Figure 6-11).

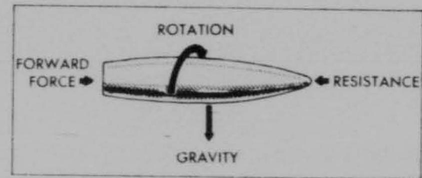

Figure 6–11. Four Factors Affecting Projectiles.

Force. The pressure exerted from explosion of the propellant against the rear of the projectile.

Rotation. The speed of rotation of the projectile depends upon the amount of twist in the rifling and the velocity of the projectile. The spin of the projectile causes it to drift laterally. For example when the cal. 30.06 rifle is fired the bullet will drift slightly to the left up to 500 yards, and then over to the right. This is due to the lateral jump when the weapon is fired. The rotation effect of the bullet stabilizes it in flight.

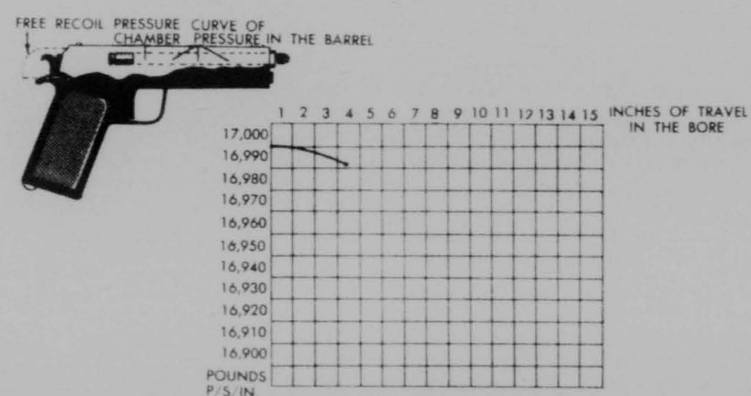

Figure 6–10. Internal Ballistics.

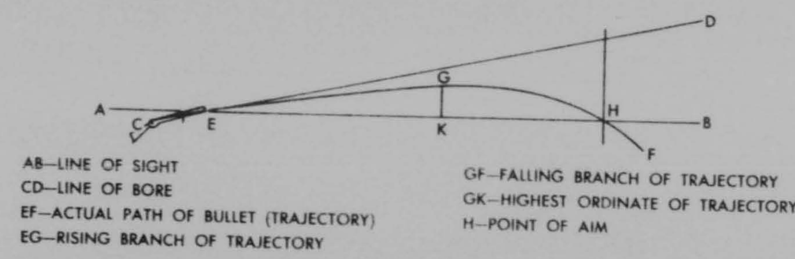

Figure 6–12. Trajectory, Vertical Scale Exaggerated.

Resistance. The travel of the projectile through the atmosphere will cause a reduction in speed. The further the range the slower the projectile. When the velocity is increased the resistance also increases. The air resistance increases with increased velocity at a rate equal to the square of the increase in velocity. Thus a bullet at 2000 feet per second meets four times the resistance of the bullet at 1000 feet per second.

Gravity. A freely falling body accelerates at the rate of 32 feet per second. This force acting on a projectile causes it to drop 16 feet during the first second, 48 feet during the second second, and 80 feet during the third second, et cetera. The line of sight is level and straight from the eye to the target. Therefore, the sights on a weapon must be so arranged that the barrel is pointed upward, and when the weapon is fired the actual path of the projectile will then rise above the line of sight and come back to the line of sight at its target. The arching of the projectile in its trajectory is called **rising branch.** The point where the projectile begins to fall is called the **falling branch.** The extreme height of the trajectory, above the line of sight at any point is called the "ordinate" of the trajectory. (See Figure 6-12).

In military terms the danger space or point-blank range of a cartridge is the total distance over which the highest ordinate of trajectory does not exceed one half of the height of a standing man plus the distance beyond coincidence of the point of aim. Thus, when aiming at a man's belt buckle the bullet will not pass above his head nor below his feet.

Modern ammunition and weapons have greatly increased the danger space by their higher muzzle velocity and more effectively shaped projectiles. During the eighteenth century the danger space of small-arms ammunition was 125 yards. Present day military loads average 600 yards or better.

Muzzle or impact energy is the striking force of the projectile at the muzzle end of the barrel or at any given point along the path of trajectory of the projectile. It is expressed in foot pounds. Foot-pound is a unit of energy required to raise one pound of avoirdupois one foot against the force of gravity.

Extreme range is the distance over which a projectile will travel, before it will hit the ground, when the barrel of the weapon is held at the proper angle to give maximum efficiency.

Barrage range is used in machine-gun fire and denotes the distance a series of shots can be controlled so that they will score hits on the target with little dispersal.

Cone of fire is the pattern made by a number of shots fired from one or more weapons at the same target.

Uniformity of Ammunition

In firing any type of ammunition from a weapon, accuracy depends on uniformity as to

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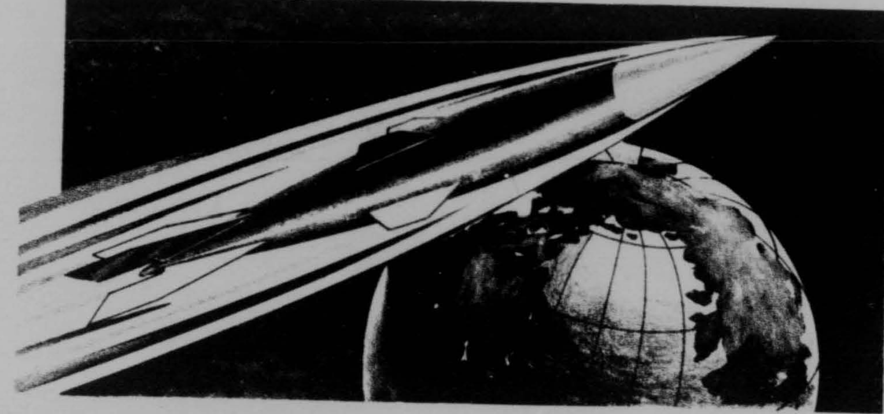
the shape of the projectile, weight, concentricity, seating, crimping, case size, powder charge, powder characteristics, primer, and the over-all dimension. The variation of air between shots will result in very little deviation of the projectile, assuming that the air remains constant. But the projectile is affected chiefly by what happens inside the barrel or in the manufacture of the weapon and the ammunition.

Future development and further study is in progress to increase the accuracy and efficiency of weapons and ammunition. The great difficulty encountered in trying to speed up the velocity of projectiles is the rapid wearing away of the riflings within the weapon. However, much progress has been achieved in reaching a much higher velocity over what books and pamphlets now state.

2. SUMMARY

In the foregoing statements and conclusions, only the basic factors of the ballistics problem has been touched. A multitude of complicated problems and study still remains in this field. They are too complex for inclusion in this text.

CHAPTER 7—BOMBS, ROCKETS AND FUZES



SECTION I—BOMBS AND RELATED FUZES

1. HISTORY

General

Fleets of bombers operated over vital enemy targets and at great distances from their home base during World War II. They proved themselves to be of great strategic value. Warfare as carried on by prehistoric man, who dropped rocks and spears from cliffs and trees upon his enemy, was only the beginning of the highly technical practice of bombing as it was accomplished during the last war. As the years went by, man became more advanced and made new discoveries. Yet as his armies became more complex, it was still found advantageous to fight from heights to gain the "upper hand" over his enemy.

Developments After World War I

At the end of World War I, the civilized world fully realized the value and importance of the airplane and the high-explosive bomb as an offensive weapon. During the years following the war, there was great activity in bomb and bomb-fuze development as well as in the field of bomb ballistics. When bombs were first used, they were suspended vertically, nose down in a rack. It was soon discovered that this was not the correct position and that a bomb must be started off in a horizontal position tangent to its true trajectory. As the lifting power of aircraft increased so did the size of the bombs (from 600 pounds to 4000 pounds within a period of two years). The first 4000-pound bomb was made in 1921, although the United States had only one type of plane which would carry one of these bombs. Careful studies were made in the field of tactical uses for bombs. Experiments were carried out to determine the economical limits of sizes for various bombs. It was decided that there should be three types: **fragmentation bombs**, **chemical bombs**, and **demolition bombs**.

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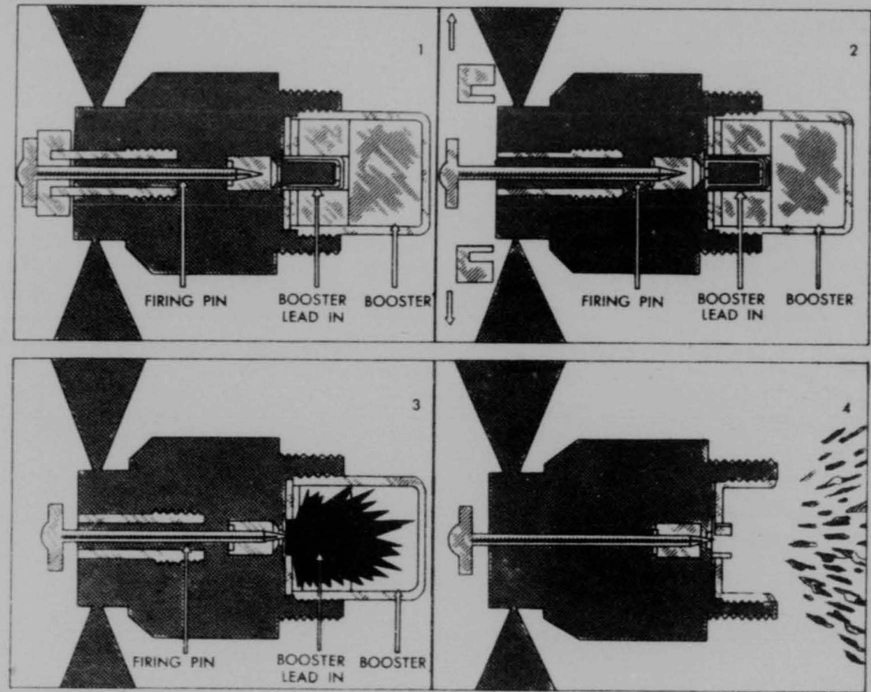

1. THE BOMB IS IN FLIGHT, BUT THE ARMING ACTION (IN THIS CASE A PROPELLER-LIKE VANE, SPINNING IN THE AIR STREAM) STILL HOLDS A COLLAR BETWEEN THE STRIKER HEAD (WITH ITS FIRING PIN) AND THE PRIMER.
2. NOW THE COLLAR HAS BEEN RELEASED AND FLIES OFF IN THREE PARTS.
3. THE BOMB HAS STRUCK, THE FIRING PIN IS FORCED INTO THE PRIMER, WHICH DETONATES THE BOOSTER LEAD-IN. THIS IN TURN DETONATES THE BOOSTER.
4. THE BOOSTER'S DETONATION SETS OFF THE BOMB'S MAIN EXPLOSIVE CHARGE.

Figure 7—1. Explosive Train.

"Frags" were to be used solely against personnel in the open. Chemical bombs were to be used whenever it was desired to prevent enemy observation of troop movement. Demolition bombs were to be used for the destruction of material targets.

2. THE BOMB

Definition

A bomb is defined as an item of ammunition dropped from an aircraft, and consists of case filled with explosive or chemical agents, and a means of exploding or scattering the charge at the target. Aircraft torpedoes, submarine mines planted by aircraft, rockets, pyrotechnics, and mortar bombs will be described later.

The Explosive Train

A bomb body is filled with high explosive. One characteristic of this explosive is that it is insensitive to ordinary shock and heat. To make it detonate, a smaller quantity of more sensitive explosive must be detonated in immediate contact with it. In a small-arms cartridge, smokeless powder, relatively insensi-

tive, is ignited by the very small but very sensitive primer. But even with more insensitive explosives like TNT a small primer is not enough; it must be amplified by a detonator of less sensitivity and larger quantity. In the larger type of bombs, this in turn must be amplified by a "booster" of medium sensitivity and medium quantity. The booster is often a part of the fuze. In very large bombs there may be a succession of boosters. The succession of charges from primer to main explosive charge is called the "explosive train" (Figure 7-1).

3. CLASSIFICATION

In common with other types of ammunition, bombs are classified according to filler as explosive, chemical, and inert. Explosive bombs are classified according to their use as **armor-piercing (AP)**, **semi-armor-piercing (SAP)**, **general purpose (GP)**, **depth**, **fragmentation**, and **practice.** Chemical bombs are classified according to type of filler, as **gas**, **smoke**, and **incendiary.** Inert bombs are used for practice and drill. Each of these types is described in detail in the following sections.

4. IDENTIFICATION

General

Bombs are completely identified by the standard nomenclature and the ammunition lot number which are stenciled on all packings, and, where the size of the item permits, on the item itself.

Standard Nomenclature

Standard nomenclature is established in order that each item stored and issued by the Ordnance Department may be specifically identified by name. It consists of the name, type and weight of the item and the model designation. The standard nomenclature lists (SNL) for bombs and components are SNL's, S-1, S-2, and S-3. The use of standard nomenclature is mandatory for all purposes of record, except as described in "Ammunition Identification Code."

Model

In order to distinguish between different designs of the same type, a model number is assigned at the time a design is adopted as standard. The model designation consists of the letter M followed by an arabic numeral. Modifications of the original design are indicated by the addition of the letter A and the appropriate arabic numeral to the model designation. For example, M38A2 designates the second modification of the item originally adopted as M38. Certain items have been standardized for use by both Army and Navy. This is indicated by prefixing the letters AN to the model. Items of Navy design are designated by Mark (MK) instead of model and modification by Mod. (For example, AN-Mk. 24-Mod2.)

Ammunition Lot Number

When ammunition is manufactured a lot number is assigned in accordance with pertinent specifications. The lot number represents a quantity of ammunition items, or ammunition components, which have been manufactured under conditions as nearly identical as possible, and which may, therefore, be expected to function uniformly. It consists of a series of letters and numerals representing the loader's lot number, the loader's symbol or initials and the date loaded. The ammunition lot number is required for purposes of record involving the particular ammunition, especially reports on condition, functioning, or accidents.

Ammunition Identification Code

In order to facilitate requisitions and records in the field, a five-character code symbol is assigned each item of ammunition issued. These code symbols are listed in ammunition SNL's.

Data Card

The ammunition data card is a five by eight inch card prepared for each lot of ammunition and forwarded with each shipment of ammunition. In addition to the ammunition lot number, it gives the lot numbers of the components and other pertinent information concerning the lot of ammunition. When required, instructions for assembly are printed on the reverse of the card.

BOMB	BODY	BANDS	MARKING
HIGH EXPLOSIVE: (G.P., Demo., AP., SAP., Frag*)			
Filled with TNT or Amatol	Olive Drab	Nose: One ½" yellow Tail: One ½" yellow	Black
Filled with Comp B	Olive Drab	Nose: Two ½" yellow Tail: Two ½" yellow	Black "Comp B" stenciled on one nose band and one tail band.
PRACTICE	Light Blue	None	White
DRILL	Olive Drab	Nose: One ½" black Tail: One ½" black	Black: Drill (inert)
CHEMICAL			
Nonpersistent gas	Blue-Gray	1 Green, nose, tail, and center	Green
Persistent gas	Blue-Gray	2 Green, nose, tail, and center	Green
Irritant smoke (Vomiting gas)	Blue-Gray	1 Red, nose, tail, and center	Red
Screening Smoke	Blue-Gray	1 Yellow, nose, tail, and center	Yellow
Incendiary	Olive Drab	1 Purple, nose, tail, and center	Purple

* Small fragmentation bombs: nose and tail painted yellow (no bands),
Body ---------- Olive Drab.

MARKING: FUZES

Fuzes are stenciled or stamped with type and model, lot number, number, and length of delay.

PAINTING AND MARKING: PRIMER DETONATORS

Head Painted:
All black - 0.1 Sec. delay
½ black - 0.05 Sec. dealy
¼ black - 0.025 Sec. delay
1/8 black - 0.01 Sec. delay
All white ------------ Nondelay

Figure 7—2. Painting and Marking Bombs.

5. PAINTING AND MARKING

Painting

Ammunition is painted to prevent rust and to furnish by colors a ready means of identification as to type. In addition bombs stored in the open are painted to prevent their ready detection from the air. High explosive, incendiary, and drill bombs are painted lusterless olive drab with bands to indicate the type. The colors used for these bands are yellow for high explosives, and black for drill. Fragmentation type bombs are painted on the head and base instead of with colored bands. Chemical and photoflash bombs are painted gray.

Marking

Bombs are marked with the following information: type, weight, model, filler and lot number. High explosive and drill bombs are

marked in black. Chemical bombs are identified by colored bands as follows: persistent gas by two bands; nonpersistent gas by one band; irritant gas by one red band; smoke by one yellow band; incendiary bombs by one purple band. Bomb bodies intended to be stored before loading are marked longitudinally with the word EMPTY in four equally spaced locations. When the bomb is filled, the word empty is painted over with the color of the bomb body. (Figure 7-2)

Fuzes are marked either by stenciling or stamping, with the type and model, lot number, and length of delay.

Primer detonators are marked with type and model, and length of delay. In addition the head of the primer detonator, M14, is painted to indicate the delay.

Packings which are intended to contain components of a complete round have the type and model of each component stenciled on the packing. The word "WITHOUT" is stenciled above this list until the components are packed, at which time the word "OUT" is painted over.

6. PACKING FOR SHIPMENT

In general, bombs are shipped unfuzed with the fuze holes closed with metal closing plugs. These plugs will not be removed except for inspection and for assembly of the complete round. Large bombs are shipped with two paper or metal shipping bands to protect the suspension lugs. The fin assemblies of such bombs are shipped separately in metal crates. Smaller bombs are shipped, finned, in metal crates. Small chemical and fragmentation bombs are packed in wooden boxes.

7. COMPLETE ROUND

Definition

A complete round consists of all the components and accessories necessary for the ammunition to function in the manner intended. Strictly speaking, complete round includes no more than the necessary number of each component. However, for purposes of supply, a complete round as issued may include both of the alternative components to allow for flexibility. For example, a complete round of

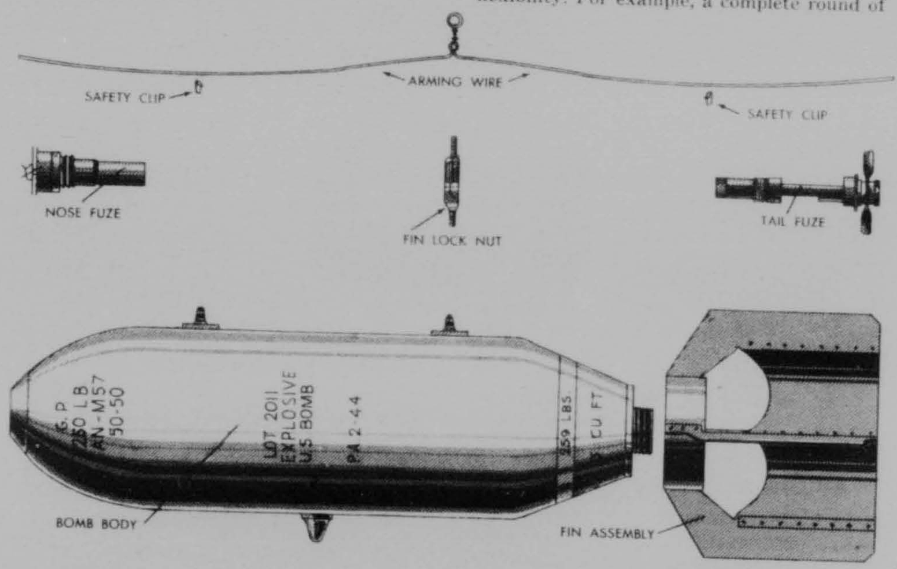

Figure 7—3. Complete Round Components.

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SERIES DEMOLITION BOMB

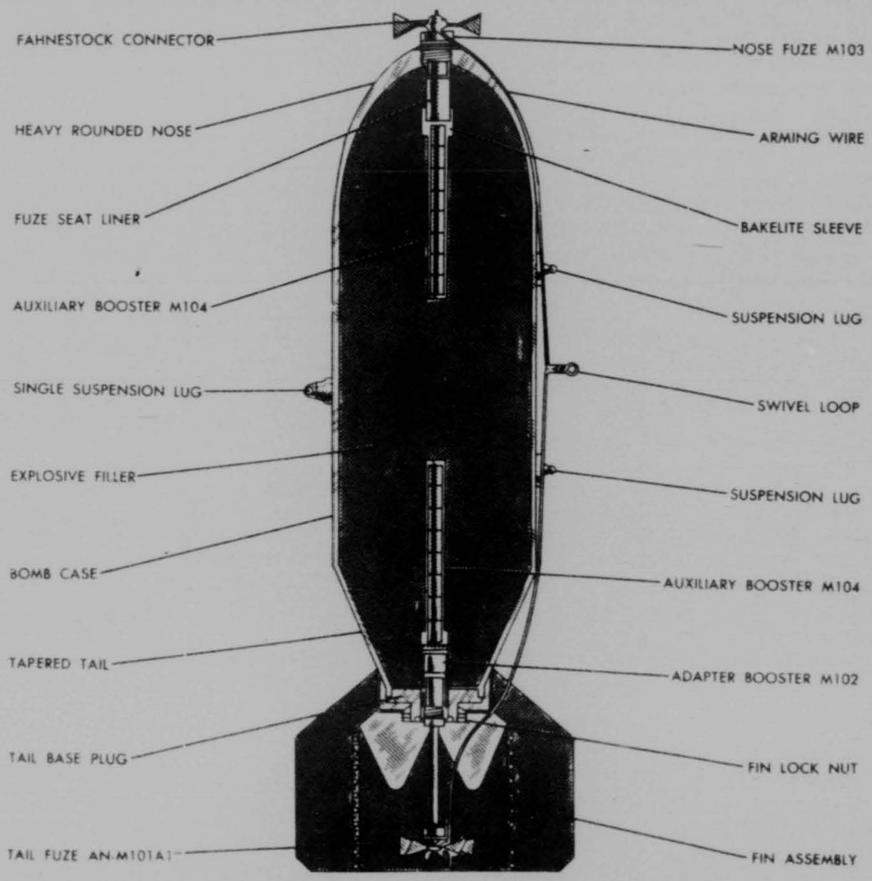


Figure 7–4. General Purpose Bomb, GP 500-Pound, AN-M43.

issue may include both a delay and a nondelay primer detonator, although only one will be used.

8. COMPONENTS OF COMPLETE ROUND AS ISSUED

In practice, it is necessary to separate various components of the complete round so that the careful handling required by one sensitive or frail component will not be necessary with an item as large and heavy as the assembled bomb. In general, the bomb is shipped in the following assemblies:

Bomb body containing explosive charge and auxiliary booster with suspension lugs attached and protected by shipping bands, and fuze cavities protected by plugs.

The fin, being light sheet metal, is shipped separately protected by a metal crate.

Fuzes contain the sensitive explosives and are given more careful handling. They are shipped separately so that if a fuse should accidentally explode, it cannot cause the explosion of the bomb.

Arming-wire assembly is shipped separately because it is small and is more easily packed separately or with smaller components than with the bomb body.

Exceptions to the general practice above will be given under the specific items as they are described in the following sections.

Percentage of Explosive

The relative amounts of explosive and metal in a bomb are dependent upon the use for which the bomb is designed.

Chemical Fillers

Chemical fillers, commonly known as chemical warfare agents, have been referred to as the weapons which "shoot around corners," due to their ability to filter through small crevices and to settle in all recesses thus seeking out their victims. History shows that chemicals as used in warfare were present in military activity as far back as 428 B.C., when, during a siege, wood was saturated with sulphur and pitch, burned under the wall of a city and produced checking poisonous gases. Chemical fillers have now become known as any substance which by its ordinary and direct chemical action produces a powerful physiological effect, a screening smoke, or an incendiary action. All of these agents are common fillers for aircraft bombs. A recent development in chemical fillers which was proven to be the most effective incendiary agent is the fire bomb. It is simply a fighter craft wing or auxiliary tank containing Quartermaster 72 Octane gasoline thickened with Napalm powder. The cheapness of manufacture, simplicity of assembly, spread, and intensity of the burning caused this bomb to be used extensively in areas where the enemy materiel was of a highly inflammable nature.

9. BOMB TYPES

General Purpose

The general-purpose bomb (Figure 7-4) is designed to meet the requirements of the great majority of bombing situations. The various models range in weight from 100 to 2000 pounds and the percentage of explosive in this type averages 50 per cent of the total loaded weight of the bomb. This proportion of filler weight to the total weight was selected so as to give a type of bomb which is suitable for general, all-around, aerial bombing of a great variety of targets. General-purpose bombs may be used for blast, fragmentation, or mining effect. They are adapted for (designed for use with) both nose and tail fuzes. Nose fuzes produce more efficient surface effect and tail fuzes produce more efficient deep (mining) effect. Both fuzes are generally used, the secondary fuze being used as insurance against malfunction. The general-purpose bomb has a cylindrical body which tapers in an ogive to the nose and in a straight cone to the base plug closing the tail end. It has two suspension lugs for double-hook suspension welded to the case on one side, and diametrically opposite, one lug for single suspension. Double-suspension lugs are spaced 14 inches apart on bombs weighing 1,000 pounds and less; they are spaced 30 inches apart on bombs weighing 2,000 pounds and more. The metal case is strong enough not to rupture on impact with heavy armor or high-strength, reinforced-concrete structures. General-purpose bombs are generally loaded with TNT or Comp B.

Light Case

The light-case, 4,000-pound bomb with a charge-weight ratio of 75 per cent is highly effective as a blast bomb for targets requiring no penetration. Since strength of case has been sacrificed to maximum charge, this type of bomb cannot be used for penetration. It must be fuzed to explode before the case breaks up on impact and therefore should be employed only on those targets against which surface blast is effective. In other respects this type resembles the general purpose described above.

Armor-piercing

Standard AP bombs are available in 1,000-pound and 1,600-pound sizes. This type of bomb is designed to pierce the heavy deck armor of modern battleships. The case is extremely heavy and as a consequence the percentage of explosive is about 15 per cent. In order to be effective, armor-piercing bombs must score direct hits. The effect of a near miss is small, due to the comparatively small amount of explosive. This type should not be used against unarmored or lightly armored ships because, being fuzed with a delay fuze to permit penetration of armor, the bomb would pass entirely through a light target before exploding. Armor-piercing bombs are streamlined in shape and adapted for tail fuze only. Suspension lugs are bolted to the body when the round is assembled for use. Early models used suspension bands with the lugs attached to the bands. Some armor-piercing bombs were made by converting armor-piercing shell, and average 5 per cent explosive. Armor-piercing bombs are loaded with explosive D.

Semi-armor-piercing

Standard SAP bombs are available in 500-pound and 1,000-pound sizes. This type resembles general-purpose bombs except that the bomb body is heavier and the explosive charge is approximately 30 per cent. It may be used against lightly-armored targets or, because of the heavy case providing better fragmentation, against concentration of personnel and materiel.

Depth

The depth bomb is a light-case type of bomb, designed for use against submarines, containing approximately 79 per cent of its total weight in explosive filler. The case is cylindrical and has a flat nose to reduce or prevent ricochet when dropped from planes flying at low altitudes. The depth bomb is fuzed with a hydrostatic fuze which functions at a predetermined depth rather than on impact. While a hydrostatic fuze may be of the nose or tail type, it is often designed for installation in a cavity running transversely through the body of the bomb. There is at the present time one depth bomb used by the Air Force. The weight of this bomb is 350 pounds. The explosive filler in this bomb is HBX. This explosive is composed of the following: 40 per cent RDX (research development explosive), 38 per cent TNT, 17 per cent aluminum powder, and 5 per cent desensitizer.

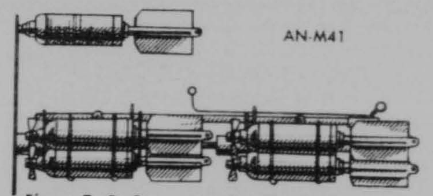


Figure 7—5. Fragmentation Cluster.

Fragmentation

Fragmentation bombs are designed to produce their effect through projection of the fragments of the body and are intended for use against personnel and light materiel. They are available in the following sizes:

M83, Butterfly	(4 lb. type), Wt. 4 lbs.
AN-M41A1, Frag	(20 lb. type), Wt. 20 lbs.
An-M40A1, Parafrag	(23 lb. type), Wt. 25 lbs.
M72A1, Parafrag	(23 lb. type), Wt. 24, 25 lbs.
M82 (T9), Frag	(90 lb. type), Wt. 86, 87 lbs.
M86 (T13), Parafrag	(110 lb. type), Wt. 118 lbs.
AN-M81 (T10), Frag	(260 lb. type), Wt. 261, 263 lbs.

Clusters are available in 100-pound and 500-pound types:

100 lb. cluster:	
M28, (24 4 lb. M83s)	Wt. 155 lbs.
M4A2, (3 23 lb. Parafrags)	Wt. 87 lbs.
M1A1, (6 20 lb. Frags)	Wt. 125 lbs.
500 lb. cluster:	
M26 (T4), (20 20 lb. M41s)	Wt. 583 lbs.
M27 (T8), (6 90 lb. M82s)	Wt. 590 lbs.
M29, (90 4 lb. M83s)	Wt. 415 lbs.

When employed in sufficient numbers to cover large areas, either from high altitudes as clusters of stabilized bombs, or from minimum altitudes with parachutes, fragmentation bombs will effectively damage light materiel targets such as radar equipment and antennas, aircraft, vehicles, antiaircraft, light artillery, mortars, and machine guns, and will produce extensive casualties to exposed personnel. Although present information is inadequate, it is believed that the 260-pound fragmentation bomb will be effective against heavier materiel. Tests are now underway to determine the relative effectiveness of the 90-pound and 260-pound fragmentation bombs. Where aircraft or light material targets are protected from lateral damage by revetments, the greater quantity and dispersion of the 20-pound fragmentation bomb and the possibilities of carpeting the entire target area render the use of this bomb preferable to other types of fragmentation bombs. The M28 cluster of twenty-four bombs and the M29 cluster of ninety bombs are considered to be highly effective against personnel within a radius of twenty feet. The explosive charge of the fragmentation type averages 14 per cent. The body walls are of uniform thickness and may be made up of steel coils, while the armor-piercing bomb which also may be a 14 per cent bomb, has the weight and thickness of metal concentrated toward the nose. One type of fragmentation bomb is stabilized by fins. The other, designed for low-altitude bombing, is equipped with a parachute to delay the impact of the bomb until the airplane has cleared the danger area. Some bombs can be fuzed in various ways designed to function on or above the surface of the ground. One fuzing allows the bomb to burst approximately five seconds after the cluster opens or on impact with the ground, depending on the setting. A second fuzing provides a mechanical time setting which detonates the bomb in from five to thirty minutes after arming. A third, the anti-disturbance fuze, becomes fully armed approximately two seconds after impact and will detonate the bomb when slightly disturbed at any time thereafter. Fragmentation bombs are usually loaded with TNT or Comp. B.

Chemical Bombs

Gas and smoke have a light metal case which acts only as a container for the chemical agent up to the time the bomb strikes the ground. These bombs are equipped with superquick fuzes because any penetration of the bomb would carry the chemical agent under ground, wasting the charge. The bomb case is opened and the charge scattered by a burster which is an explosive element resembling the booster and auxiliary booster of explosive bombs. Some bursters are long tubes of explosive which are located along the axis of the bomb.

Incendiary bombs are of two types; one has a case similar to the gas and smoke bombs and is loaded with a charge of inflammable material such as oil; the other type has a heavy magnesium alloy case containing an igniting charge and the case itself acts as the main charge of the bomb.

Photoflash Bombs

This type is a pyrotechnic item but is classed with bombs because of its explosive effect. It is a light case bomb with a charge of flashlight powder instead of high explosive.

Practice

This type of bomb is provided for target practice. There is a wide range of types and weights in order to represent all types of service bombs. Some practice bombs have a fuze and a spotting charge; others are completely inert. Some are sand loaded to weight at point of use, others are constructed to weight. Each model is described in the following section.

Drill Bombs

Completely inert bombs and components are supplied for the training, and practice of ground crews. Each type and weight of service bomb is represented by a corresponding drill bomb. Drill bombs are made up from the metal parts of service bombs, inert loaded when necessary. They are used for practice fuzing, unfuzing, and handling. Drill bombs, unlike inert practice bombs, are not expendable; they are not to be used for bombing practice.

Gauge Bombs

Completely inert bombs are furnished to the Air Force by the Ordnance Department for use in gauging and testing aircraft. Such bombs are not issued to the field.

10. COMPONENTS—BOMBS

Complete Round

The components of a complete round are, in general, as follows (Figure 7-3):

Bomb, unfuzed, w o fin. This is composed of bomb body with explosive charge and auxiliary booster, fuze-seat liner, base plug with fin-lock nut and adapter-booster, suspension bands (when lugs are not attached directly to bomb body), shipping bands or packing crate, and nose and tail closing.

Nose fuze (not included in AP bombs).

Tail fuze (not included in small chemical or small fragmentation bombs).

Fin assembly (attached to bomb in smaller sizes).

Arming wire assembly.

Trunnion band (for dive bombing only).

Bomb Body

Fuze-seat Liner. The fuze-seat liner is a metal cap which is assembled inside the nose of the bomb to keep a cavity clear for assembling the nose fuze.

Base Plug. The base plug closes the filling hole and forms the base of the bomb. The tail fuze adapter-booster is screwed into the base plug. An extension of the plug to the rear is threaded to provide for attachment of the fin assembly by means of the fin-lock nut. For shipping, the fin-lock nut is covered by a fiber protector and is wired in place. In bombs of current manufacture the base plug has studs extending into the explosion charge to prevent removal of the plug.

Adapter-booster. An adapter is a bushing threaded on the outside for assembly to the bomb body and on the inside for assembly of the fuze. When the booster is assembled to the adapter, the assembly is known as an adapter-booster. Tail adapter-boosters of high explosion and chemical bombs are drilled for the insertion of lock pins to prevent their removal.

Suspension Bands. When, for any reason, it is inadvisable to weld or bolt suspension lugs to the bomb body, the lugs are attached to metal bands which are bolted around the bomb body. When suspension bands are to be installed, their position is indicated by a band painted on the bomb.

Shipping Bands. Shipping bands are attached to the bomb to protect the suspension lugs. They may be compressed paper with a recess for the lugs or may be of metal in the form of a U-shaped channel. They are not removed until the bomb is prepared for use.

Closing Plugs. The openings to the fuze cavities are closed during shipping and storage by metal plugs. Those plugs serve to protect the fuze-seat cavity and threads. They may be removed only for inspection or for fuzing the bomb. If a bomb is returned to storage after being prepared for use, the fuzes are removed and the fuze hole plugs replaced.

Fin Assembly. The fin assembly provides for stability of the bomb in flight. Some bombs of one hundred pounds and smaller size have the fin assembled to the bomb body before shipment. Larger bombs are shipped with fin unassembled. In such cases the fin assembly is packed in a metal crate. The fin assembly consists of a fin sleeve which fits over the tail of the bomb and is held in place by the fin-lock nut. The sheet-metal fin blades are riveted or spot welded to the fin sleeve and, with the supporting members, forms a square box. Fins should be protected against bending or other distortion because such distortion materially alters the flight of the bomb.

Trunnion Bands. When trunnion mounting is desired for dive bombers, the trunnions are mounted on a steel band which is bolted to the bomb body in the same manner as suspension bands. The center of gravity band or the single suspension lug serves to indicate the proper location of the trunnion band. AP bombs are drilled and threaded so that the trunnions may be screwed into the bomb body.

SECTION II—FUZES

1. GENERAL

A fuze is a mechanical device designated to initiate a detonation under the circumstances desired. Fuzes are classified according to position as nose, tail, and transverse, and according to function as time, impact, and hydrostatic. Time fuzes function a predetermined number of seconds after the arming pin is released; impact fuzes function after the bomb strikes a resistant material; and hydrostatic fuzes function by water pressure. Impact fuzes are classified as delay when they are designed to have a definite time between impact and explosion of the bomb, and as superquick (nose) or nondelay (tail) when there is no delay element incorporated.

Arming

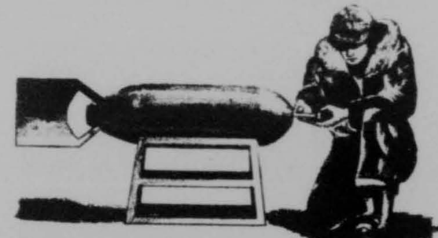
Bomb fuzes are shipped in a safe condition. They are so constructed that, while they are unarmed, they cannot function. A detonator safe fuze is one in which the detonator is out of line with the firing pin until the fuze arms.

Nose Fuzes

Nose fuzes generally are held unarmed by the presence of safety blocks between the striker and the fuze body thus preventing the firing pin from being driven into the primer. (Figure 7-6)

Tail Fuzes

Tail fuzes, in general, are held unarmed by an arming item being screwed into the inertia type of firing pin. The booster is not assembled to the fuze in this case; it is located in the adapter-booster assembled to the bomb.



"Fuzing a Bomb"

2. CLASSIFICATION OF FUZES

Position

Fuzes are classified according to the position in which they are assembled to the bomb as nose, tail and transverse.

Arming

Fuzes are classified according to method of arming as arming-pin type and arming-vane type. These are further classified as:

Direct Arming. When the fuze becomes armed immediately on the ejection of the arming pin or by direct unscrewing of the arming stem by the vane.

Delayed Arming. When the ejection of the arming pin initiates a powder train or clock-like mechanism which arms the fuze after a predetermined time or when the arming vane is connected to the arming stem by a reduction-gear assembly.

Action

Fuzes are classified according to action as time, impact, and hydrostatic.

Time fuzes function to explode the bomb a certain number of seconds after release. Time fuzes act in a manner similar to an ordinary alarm clock.

Hydrostatic Fuzes

This type works on the principle of a bellows or diaphragm working against a spring of fixed strength. When the external pressure overcomes the resistance of the spring the firing pin is released and driven against the primer by spring action. In some fuzes, provision is made for adjustment by a mechanism controlling the compression of the diaphragm spring. This is set by an external lever. In other fuzes, adjustment is obtained by interchanging the spring.

Primer Detonators

In order to allow variation of the delay action of tail fuzes, primer, delay element, and

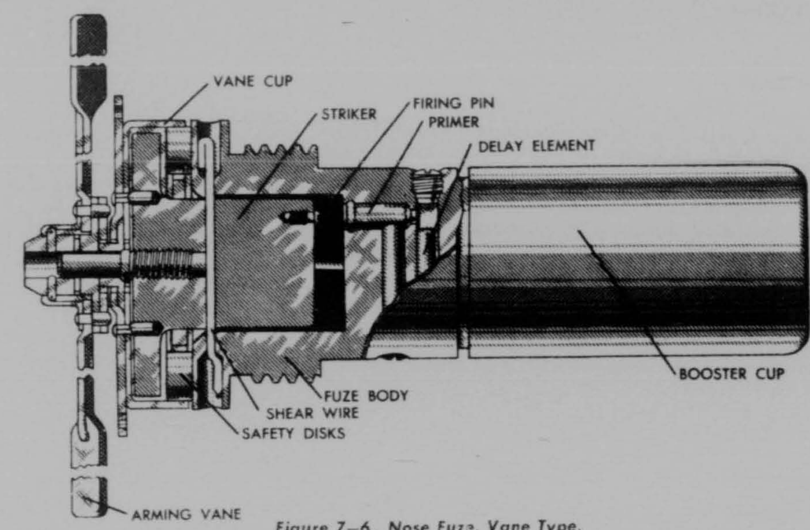


Figure 7—6. Nose Fuze, Vane Type.

detonator are assembled in one interchangeable unit. Primer detonators of various delay times are supplied. Primer detonator, M14 is supplied with 0.1 second delay, 0.025 second delay, 0.01 second delay and non-delay. Primer detonator M16 and M16A1, are supplied with 8 to 15 second delay and 4 to 5 seconds delay.

Arming Vane

In general, vane types of fuzes are packed and shipped with the arming vane removed. The vane assembly is packed separately and shipped in the same box.

3. IDENTIFICATION OF FUZES

Fuzes are identified by the information marked on the containers and stamped on the fuze body. They may be identified by inspection as herein described. Detailed differences are as follows: Rapid-arming tail fuzes are distinguished from slow-arming types by the rod which extends from the arming head forward along the arming stem for approximately 1.5 inches. This rod is present on the slower-arming types and absent from the rapid type. Fuzes of one series (that is, fuzes with the same mechanism and action, but designed for bombs of different sizes) are distinguished among themselves by the length of the arming stem. Special-purpose fuzes such as hydrostatic have a distinctive appearance and method of operation. They are described in the following sections.

4. FUZE EXTENSION

The most efficient use of fragmentation and chemical bombs requires that they detonate at or slightly above the surface of the ground. The nose fuze extension consists of a steel tube, filled with tetrytol, adapted to receive the fuze and screw into the fuze seat of the bomb.

5. NOSE ADAPTER-BOOSTER

Large bombs are adapted for large-diameter nose fuzes. An adapter-booster which is threaded externally to fit the large fuze seat and internally to receive the smaller fuze is necessary in order to use smaller special-purpose fuzes with these bombs.

6. PRECAUTIONS

Fuzes are packed in sealed moisture-proof containers. They must not be unsealed until

required for use; fuzes unpacked for use and not used are resealed and returned to their original packings which must be effectively sealed with tape.

Fuzes must be protected from excessive heat.

Fuzes must be handled with care at all times. Boxes should not be dropped, tumbled, dragged, or thrown; nor may they be struck with a hammer or similar tool either to open the box or align in a stack.

Fuzes should not be unpacked or packed within one hundred feet of a magazine containing explosives.

When the fuze is unpacked it should be examined to insure that shipping seals are intact, that safety blocks or arming pins are in place and that the arming stem is not unscrewed.

Safety cotter pins, shipping wires, and seals must be left in place until the arming wire is assembled to the fuze.

Care should be exercised not to bend or distort vane assemblies.

Only primer detonators authorized for use with the particular fuze may be used.

When an authorized alteration is made to a fuze, the fuze must be so marked as to indicate clearly the nature of the modification. (For example, when the depth setting of a hydrostatic fuze is changed, the new depth setting is stenciled on the pistol head.) If the fuze is repacked after alteration, the container also must be marked.

Fuzes may not be disassembled further than authorized without prior approval of the Chief of Ordnance.

7. NOSE FUZES

General

Only one of the various nose fuzes will be discussed in detail in this text. For further information on other types the various Army publications may be consulted.

Fuze, Bomb, AN-M103 (Nose)

Data. Fuze, bomb, AN-M103 (nose) is a detonator-safe, arming-vane type of nose fuze which requires 230 revolutions of the vane to arm for delay action and 345 revolutions to arm for instantaneous action. It is designed to detonate the bomb on impact, either instantaneously, or with 0.1 second delay, dependent upon the setting of a delay pin. The fuze has an overall length of 7.1 inches, and weighs 3.7 pounds. Fuze, bomb, AN-M103 (nose), is authorized for use in all G.P., demolition, and S.A.P. bombs when the tail fuze used has a delay of 0.1 second or less. It may also be used in depth bombs (except AN-Mk. 17) and G.P. bombs with hydrostatic fuzes, but only if selective arming racks are available. Fuze, bomb, M103 (nose) is an earlier model which differs from AN-M103 in requiring 785 revolutions of the vane to arm the fuze. In other respects, information given herein concerning the AN-M103 applies equally to the M103.

Description. Fuze, bomb, AN-M103 (nose) is cylindrical in shape. (See Figure 7-7.) The inner portion which assembles inside the fuze seat in the bomb is 5 inches in length and 1 3/4 inches in diameter. The outer portion is 1 1/4 inches long and 2 1/2 inches in diameter. The arming-vane hub projects 3/4 of an inch from the outer end. The two-blade arming vane is shipped separately. A vane stop which consists of two straps attached to the vane hub and fuze top respectively, is fastened during shipping and handling by a safety cotter pin and a sealed shipping wire. On the side of the fuze, there are two diametrically-opposed lugs which serve to prevent the hand slipping when fuzing or unfuzing the bomb. The setting pin is located on the circumference midway between the lugs. On the setting pin, there is a cross member which forms a key and rests in one of two slots in the pin seat; when the key is in the deep slot the fuze is set for delay and when the key is in the shallow slot, the fuze is set for superquick action.

Function. The fuze contains four interrelated systems, arming, delay-selecting, firing, and the explosive train.

The arming system consists of the arming vane (90 degrees out of position in illustration), vane cup, reduction gears, arming screw, and safety blocks. The arming vane, reduction gears, and arming screw are assembled in one unit with the vane cup; the safety

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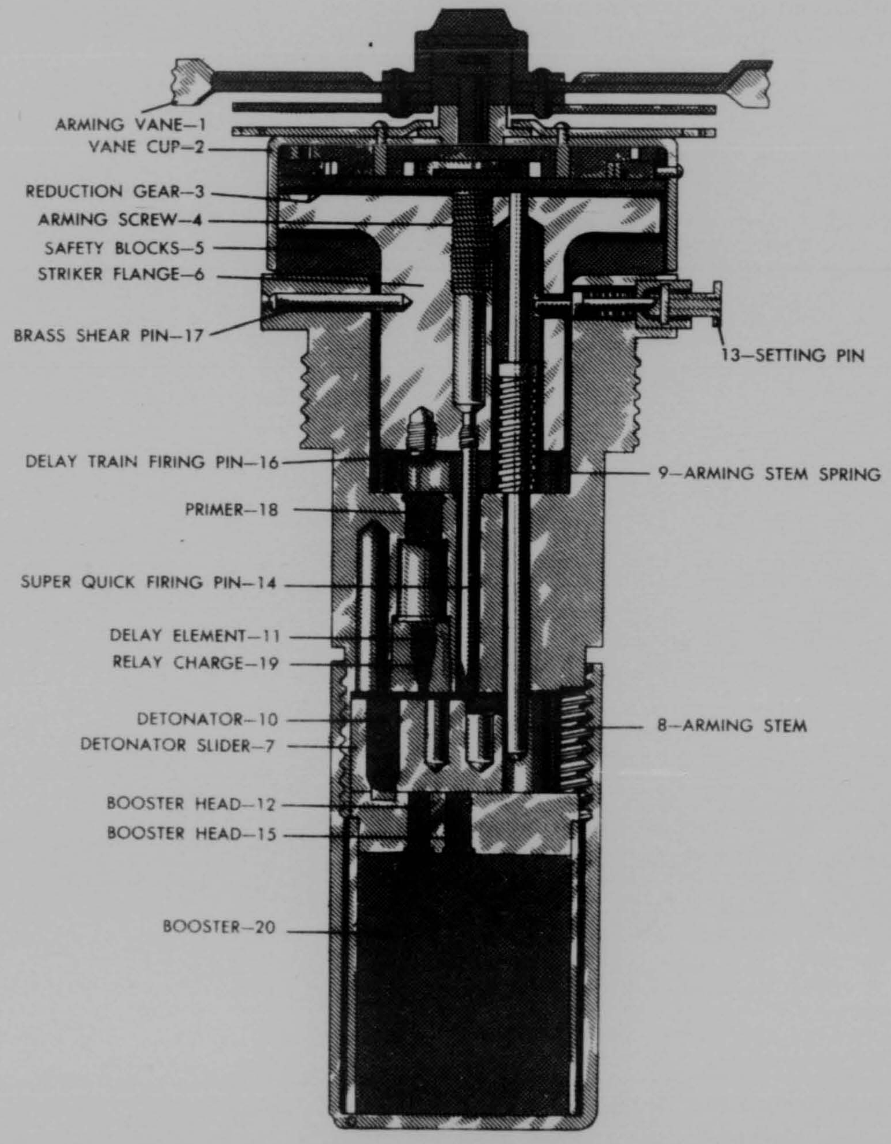

Figure 7–7. Fuze, Bomb, AN-M103 (Nose) Unarmed.

blocks are held between the flange of the striker and the fuze body by the vane cup. When the arming vane is rotated by the air stream, the arming screw unscrews from the striker body carrying the vane, gears, and vane cup with it. When the vane cup has progressed ¼ inch the safety blocks are released. Positive ejection is insured by a flat spring assembled within the circle of blocks. The arming vane continues to rotate until the arming screw has progressed ½ inch. Then the entire assembly becomes disengaged from the fuze and falls free.

The delay-selecting system consists of the detonator slider which is held in place by the arming assembly. As the arming screw advances, the arming stem follows, driven by its spring. When the stem has progressed ¼ inch, it clears the first step of the detonator slider which moves to line up the detonator with the delay element and booster lead of the explosive train. If the setting pin is in the delay position, it restrains the arming stem from moving further and, on impact, the fuze functions with 0.1 second delay. If the pin is set for superquick action, the arming stem continues to progress until the end of the stem clears the second step of the detonator slider and the slider moves to line up the detonator with the superquick firing pin and booster lead. Upon impact, the fuze will function immediately. The detonator is out of line with the other explosive elements until the fuze arms; the fuze is detonator safe.

Note: Once the fuze arms, detonator slider cannot return to its original position.

The firing system consists of a cylindrical striker and two firing pins, one for the delay train, the other for the superquick train. A flange at the outer end of the striker forms, with the fuze body, a groove which contains the safety blocks. The striker is held in place after arming by a brass shear pin and the setting pin which acts as an additional shear pin. Upon impact, after arming, the striker is driven inward shearing the pins and driving both firing pins with it.

The explosive train consists of a primer, delay element, relay charge, detonator, booster leads, and booster. The primer, delay element, and relay charge are housed in the fuze body in position to be initiated by impact of the delay firing pin. The detonator is assembled in the detonator slider and the booster is assembled to the inner end of the fuze. When the slider is set for superquick action, the superquick firing pin is driven directly into the detonator, thus serving as its own primer. The primer, delay charge, and relay charge, although fired by the delay firing pin, are bypassed, and the booster is detonated immediately.

Preparation for Use. Aside from assembling the vane to the vane hub (described below) the only preparation of the fuze necessary is the change of delay setting. This is done by pulling the setting pin out until the key clears the setting slots, turning the pin a quarter turn so that the key clears the setting slots, turning the pin a quarter turn so that the key will enter the outer slot, and letting the pin drop back. As shipped, the pin is set in the deep (delay) slot. It needs to be changed to the shallow (superquick) slot only when detonation of the bomb above ground is desired.

Fuzing and Unfuzing. Fuze, bomb, AN-M103 (nose) (Figure 7-8) is assembled to the bomb in the steps described below:

The container is unsealed and the fuze is removed from the packing.

The fuze is inspected to see that it is serviceable and to see that the setting is for superquick or delay action as desired (If the fuze is set SQ and not used, it should be reset to delay on repacking).

The seal wire is cut and removed.

The fuze, less vane, is screwed into the bomb handtight. The use of a wrench or other tool is neither necessary nor permitted.

The arming wire is uncoiled; the shorter branch is threaded first through the forward suspension lug of the bomb, then through the upper pair of eyelets in the vane stop straps. If the nearer pair is occupied by the cotter pin, another cotter pin is placed in the opposite eyelet; then the original cotter pin is removed and replaced with the arming wire.

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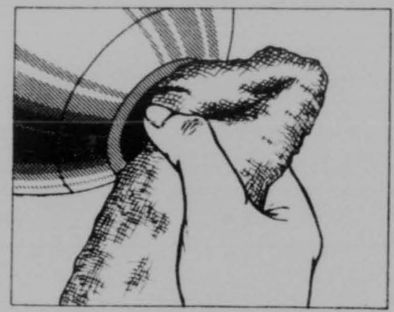
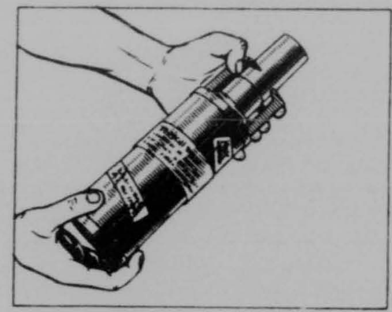
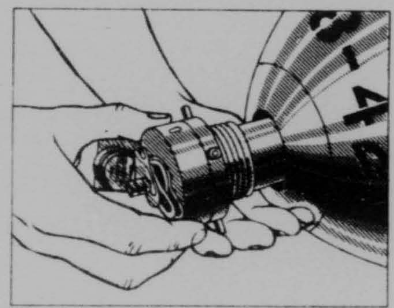


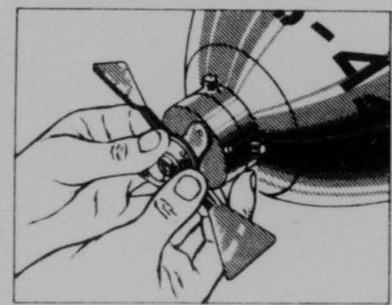
(1) AFTER REMOVING NOSE PLUG, INSPECT THREADS AND WIPE OUT ANY GREASE AND DIRT



(2) REMOVE FUZE FROM SEALED CONTAINER (IMPORTANT—KEEP THE CONTAINER IN EVENT FUZE HAS TO BE REPACKED)



(3) SCREW FUZE IN PLACE HANDTIGHT. ALWAYS CUP HAND TO GUIDE FUZE AND TO GUARD AGAINST DROPPING. A HARD BUMP CAN EXPLODE DETONATOR. NEVER TIGHTEN WITH WRENCH OR OTHER TOOL UNLESS SPECIFICALLY AUTHORIZED.



(4) PUT VANE IN PLACE BY PRESSING CENTER BUSHING. THIS AVOIDS POSSIBLE DISTORTION OF BLADES.

(5) THREAD ARMING WIRE THROUGH UPPER EYELETS. ATTACH SAFETY CLIP (A). ALLOW ARMING WIRE TO EXTEND 2½ TO 3 INCHES.
ARMING WIRE MUST BE FREE OF KINKS AND BURRS

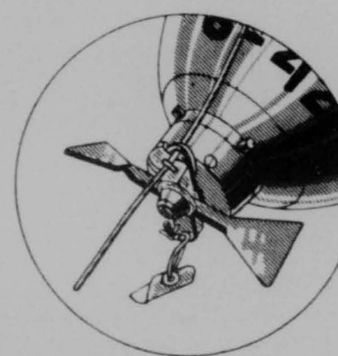


Figure 7–8. Fuzing.

The arming wire is adjusted to protrude 2 to 3 inches beyond the vane stop. One safety clip is slipped over the end of the arming wire and moved up until it just touches the face of the strap. It is important that the protruding section of wire is neither kinked nor burred.

The arming vane assembly is slipped over the vane hub so that the locating pins on the vane enter the corresponding holes in the vane hub and the vane holder spring snaps into the groove in the hub.

Note: The assembly of tail fuze and fin assembly may precede or follow the installation of nose fuze described above.

Upon completion of assembly of the round, the cotter pin and tag are removed from the vane stop.

If a bomb is not dropped it must be unfuzed and returned to storage, reversing the steps specified above.

Accidental Arming. If a fuze should be found with the vane cup advanced enough to have released the safety disks, it is armed and will function on receiving a blow or pressure on the striker. In such a case the first action taken will be to place improvised safety blocks between the flange of the striker and the fuze body and taping or otherwise fastening them in place. The improvised blocks should be of a material thick enough to take up all available space between the flange and fuze body. After the blocks are in place the fuze may be handled in comparative safety. No further attempt will be made to disarm such a fuze. It should be destroyed as unserviceable ammunition in a dangerous condition.

Partial Arming. The earlier model of this fuze, fuze, bomb, M103 (nose), may not arm before impact when released from minimum altitudes for over-water bombing. When such use is contemplated the older type fuze may be partially armed by removing the safety pin and seal wire and turning the vane hub counterclockwise for approximately 250 revolutions, until exactly $\frac{1}{8}$ inch of the thickness of the safety disks is uncovered by the vane cup. It should be noted that no more than $\frac{1}{8}$ inch of the disks should be exposed and not more than 250 turns of the vane hub be made. The seal wire and safety pin must be replaced, and the tags attached to both must be marked to show that the fuze is partially armed. If partial arming is done in advance of requirements, fuze containers will be marked. Fuze, bomb, M103 (nose), partially armed, as described above, may be employed on any mission without restoration to its original condition. Fuze, bomb, AN-M103 (nose), normally arms within minimum combat altitudes; it will not be partially armed.

Marking. The container in which the fuze is packed is marked with the nomenclature of the fuze, the ammunition lot number, the fuze assembly drawing number, and the date of its revision. The fuze has stamped in the metal of the body the type, model, and lot number. Two instruction tags are attached to the fuze as shipped. One attached to the seal wire, reads: "Remove this seal before assembling vane to fuze"; the other, attached to the safety pin, reads: "To be removed after bomb has been placed in dropping gear, arming wiring inserted. If bomb is not dropped, replace pin before removing arming wire."

Packing. The fuze, less vane, is packed in an individual, sealed, metal container. When packed in bulk, 25 such containers and vanes, mounted on spindles, are shipped in one package.

Extension Fuze, M1, Varied Lengths

This fuze may be used in any bomb adapted for the AN-M103 nose fuze. It consists of a burster support and a burster assembly. The burster support is a steel tube of 2.375 inches outside diameter which has a male thread at one end and a female thread at the other. The former screws into the adapter in the nose of the bomb; the latter receives the AN-M103 nose fuze. The burster assembly consists of an asphalt-impregnated, chipboard tube which has a recessed metal cap crimped to one end and a plain metal cap cemented to the other. The tube is filled with cast tetrytol. A shakeproof lock washer is supplied with each assembly. The various sizes of the components are as follows: Length, Overall (ins.)

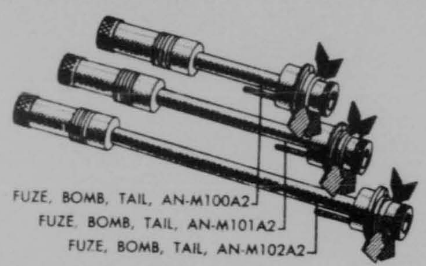


Figure 7–9. Tail Fuze Series.

Nomenclature	Burster Support	Burster Assembly
Extension, fuze, M1, 6-in.	6.72	5.92
Extension, fuze, M1, 9-in.	9.72	8.92
Extension, fuze, M1, 12-in.	12.72	11.92
Extension, fuze, M1, 18-in.	18.72	17.92
Extension, fuze, M1, 24-in.	24.72	23.92
Extension, fuze, M1, 30-in.	30.72	29.92
Extension, fuze, M1, 36-in.	36.72	35.92

Fuze, Bomb AN-M103A1 (Nose)

The later model of the AN-M103 is the AN-M103A1. The only difference between these two fuzes is a slight modification in the arming screw which has been lengthened to overlap the collar of the arming stem on the AN-M103A1. This modification was necessary because of the many accidents that were happening in crash landings.

To assemble the extension the procedure is as follows:

The arming wire must be of adequate length to reach the increased distance to the fuze.

Components are removed from their packing and inspected to be sure they are in good condition and match in size.

The fuze-hole plug of the bomb is removed and inspected.

The lock washer is placed on the booster support and the support is screwed into the nose fuze adapter. It must be tight enough for the lock washer to take hold.

The burster is inserted, crimped end first, into the support and pushed in as far as possible. It should not be forced. If the burster binds, one inspects to see whether the support or the burster is at fault and the faulty item is discarded.

The fuze is assembled in the outer end of the extension as described above.

If not used, it is returned to original condition and packing.

Extension fuze, M1, should be painted olive drab, and marked in black.

8. TAIL FUZES

Fuze, Bomb, AN-M100A2 (Tail)

Data. Fuze, bomb, AN-M100A2 (tail) (Figure 7-9) is a vane type of tail fuze which arms after 175 revolutions of the arming vane and acts to detonate the bomb on impact with a delay determined by the primer detonator used. Figure 7-10. As issued, primer detonator, M14, 0.025 second delay is assembled to the fuze This may be replaced in the field by primer detonator, M14 of 0.1 second delay, 0.01 second delay, or nondelay. The fuze is approximately 9 inches long and weighs 2.7 pounds. It is authorized for use in general-purpose and fragmentation bombs of 100 to 300 pounds. Earlier models differ as follows: Fuze, bomb, M100A1 and AN-M100A1 require 675 revolutions of the arming vane to arm the fuze. Fuze, bomb, M100 had a 0.1 second delay primer detonator permanently assembled to the fuze as well as the longer arming. All earlier types had an 8-blade vane. If earlier models are used in low altitude over water bombing, they should be partially armed as described below.

Description. Figure 7-11. Fuze, AN-M100A2 (tail) consists of body, stem, and arming head.

The body is cylindrical and is threaded to screw into the adapter of the bomb. A primer detonator, M14, is screwed into the inner end; the stem is assembled to the outer end. The body contains an inertia type of firing pin and

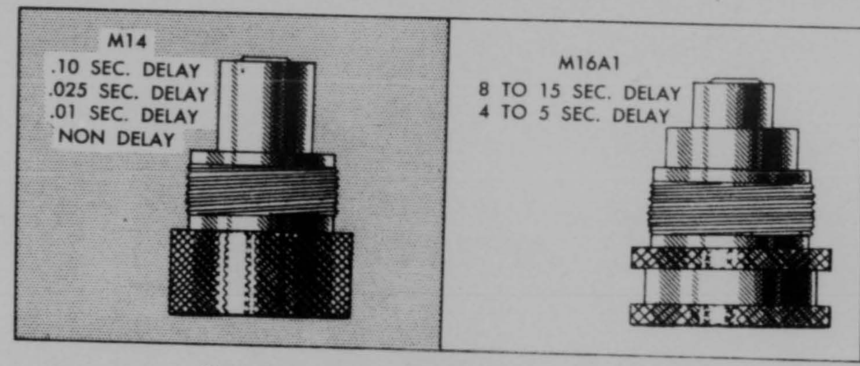


Figure 7–10. Short and Long Delay Primer Detonator.

its restraining spring. A cotter pin is placed through the body and firing pin for shipping.

The stem tube connects the body and the arming-head cup. The inner end of the arming stem is screwed through the body and into the firing-pin plunger; the arming mechanism is attached to the outer end by means of a cotter pin.

The arming head contains the arming-vane assembly and reduction-gear train. A stop rod passes through the cup and extends toward the body parallel to the stem. The arming vane is a 4-blade type and is packed separately. A safety pin is sealed into a vane stop for safety in handling.

Function. When the arming wire is withdrawn, the air steam turns the arming vane which turns the bearing-cup assembly. A pinion, mounted on the bearing cup, is in mesh with a 29-tooth fixed gear and a 30-tooth movable gear. The fixed gear is prevented from rotating by the stop rod passing through the stem cup. Each revolution of the pinion with the vane forces the movable gear one tooth 1/30 revolution ahead of the fixed gear. The fixed gear is connected to the arming stem by a cotter pin passing through the gear carrier and the arming stem. As the arming stem rotates, it unscrews from the firing-pin plunger. After 5.7 revolutions of the arming stem (approximately 175 revolutions of the vane) the stem clears the plunger and the fuze is armed.

Note: There is no external evidence that the fuze is armed other than the progress of the arming head out of the cup, shortening the amount of stop rod exposed by .6 inch. The vane assembly is still attached to the fuze. After about 200 more revolutions of the vane, the stem unscrews from the fuze body and vane; arming head and stem assembly are carried clear of the fuze by the air steam. Upon impact, the plunger is driven forward and the firing pin strikes the primer. The flame from the exploding primer ignites the delay charge which burns the required time and ignites the relay charge. This explodes the detonator.

Preparation for Use. When removed from the packing, the fuze is ready for use except for assembly of the arming vane, described below, and for possible change of the primer detonator. When a delay other than 0.025 second is required, the primer detonator is unscrewed by hand. The use of tools is neither necessary nor permitted. A primer detonator, M14 of the desired delay is removed from its packing and inspected. It is screwed hand-tight into the base of the fuze. The primer detonator removed from the fuze in the packings of the substitute is sealed and marked to indicate the delay. If the plunger spring or spring washer fall out of the fuze when the primer detonator is removed, they should be replaced before the new primer detonator is assembled.

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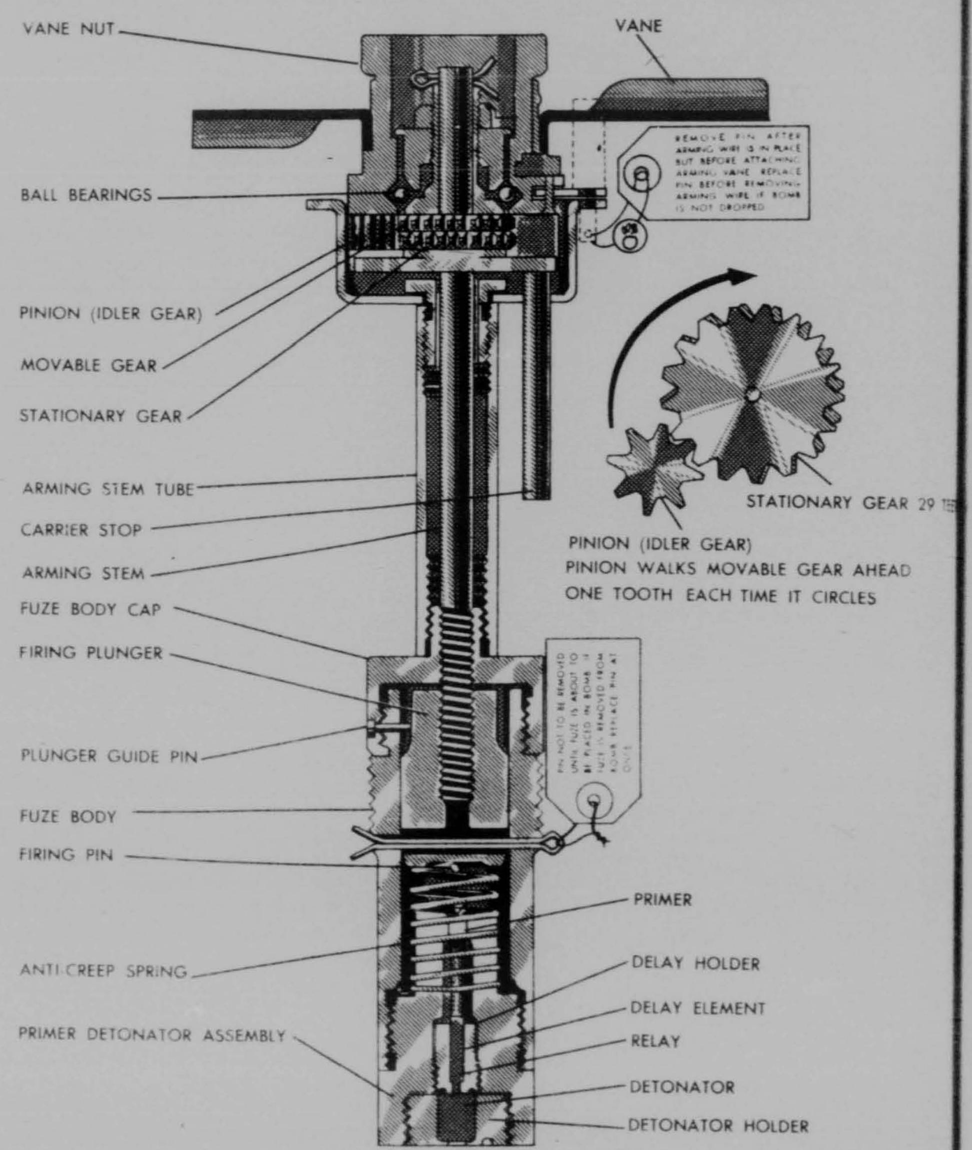

Figure 7–11. Fuze, Bomb, AN-M100A2 (Tail).

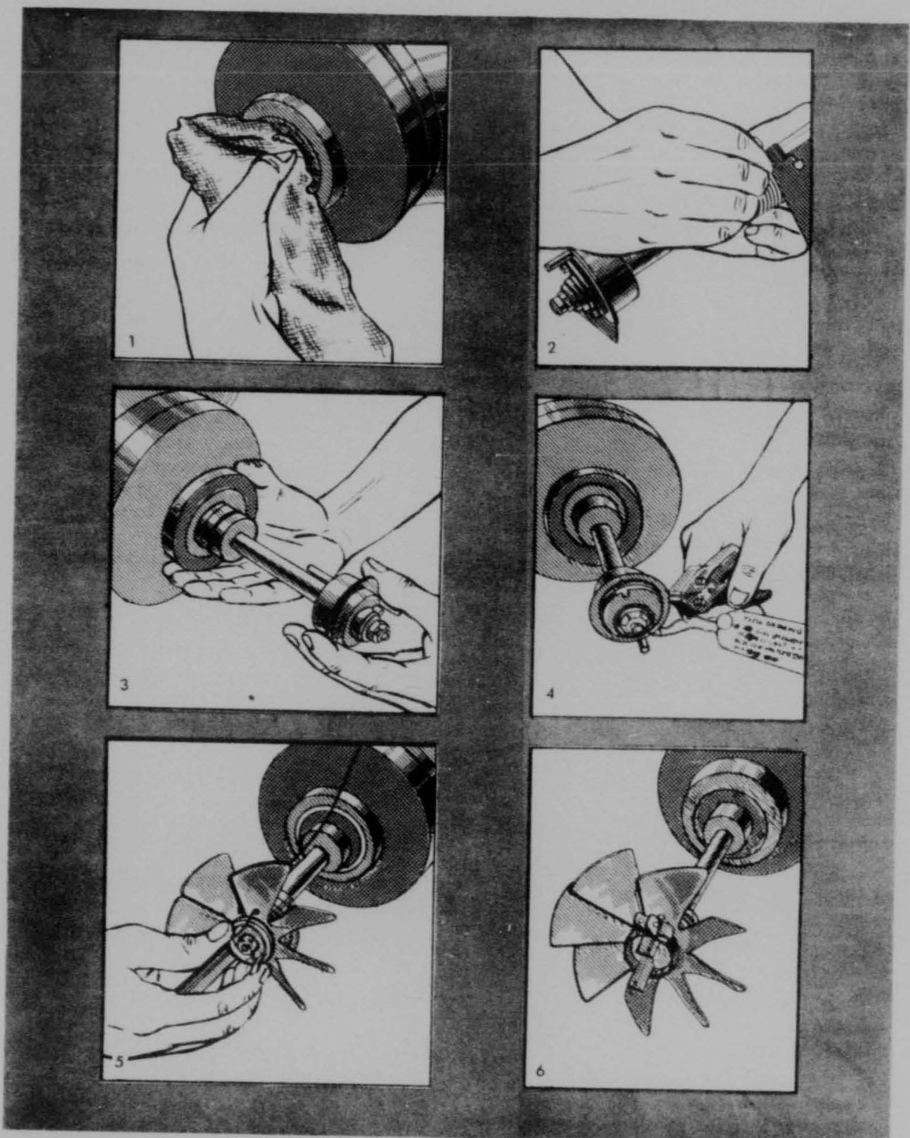

Figure 7–12. Fuzing (Tail).

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Caution: Primer detonator, M14, used in this fuze and primer detonator, M16, used in other fuzes are not interchangeable. An attempt to assemble a primer detonator to a fuze for which it is not designed will ruin both fuze and primer detonator. Primer detonators may be distinguished by the knurling around the base. The M14 has a single wide band; the M16 has two narrow bands.

Fuzing. Figure 7-12. In fuzing the bomb with fuze, bomb, AN-M100A-2 (tail), the following sequence is to be observed:

The can is unsealed and fuze removed from its packings.

Fuze is inspected for serviceability and for presence of primer detonator of desired delay.

Cotter pin which passes through body of fuze is removed.

Fuze is screwed into adapter-booster handtight.

Long branch of arming wire is threaded through rear suspension lug of bomb, then through eyelets of vane stop. If nearer eyelets of the vane stop are occupied by the safety pin, the safety pin from the fuze body is placed in opposite vane stop. The seal wire is then cut, the pin removed and the arming wire inserted.

Safety pin is removed.

The wire is threaded through hole in arming vane and vane is assembled to arming head and vane nut is screwed down handtight. Slots in vane hub must be properly located over studs.

Arming wire is adjusted to protrude two to three inches. All kinks and burrs are removed.

The safety clip is placed on the wire and moved up until it just touches the face of the vane.

If the bomb is not used, it is unfuzed and returned to storage reversing the steps listed above.

Explanation of Figure 7-12.

After removing tail plug, one wipes threads carefully, and attaches fin assembly.

One removes cotter pin in the fuze body. (Most fuzes cannot be inserted with this pin in place. Some fuzes have several pins; some none.)

Fuze is screwed into place, holding other hand below to guard against dropping or bumping detonator against bomb body. One should screw in handtight and never tighten with wrench or any other tool unless specifically directed to do so.

Car seal is removed from outer end of fuze.

Arming wire is threaded into place and put on vane.

Safety clip is put in position just touching vane. Excess arming wire is cut off so as to allow only 2½ to 3 inches to extend. It must be free of kinks and burrs.

Accidental Arming. Should this fuze become armed accidentally, as shown by the progression of the arming head and shortening of the stop rod as described above, the fuze will have first the vane assembly and then the primer detonator removed. The fuze may then be disarmed by authorized and experienced personnel as follows:

Cotter pin is placed through body of fuze.

The cotter pin is removed at the outer end of the arming stem which holds arming head on stem. Arming assembly is removed.

If there is a register hole through the stem tube and stem, arming stem is screwed into plunger until holes in the stem and stem tube are in register. A cotter pin is placed through these holes. If there is no register hole, stem is screwed down tight then backed off on turn.

Arming head is replaced on stem and cotter pin is replaced.

If used, cotter pin in stem is removed.

Primer detonator is replaced.

Partial Arming.

Fuze, bomb, AN-M100A2 (tail) will arm within the minimum combat altitudes; hence, partial arming is neither required nor permitted.

Fuze, bomb, AN-M100A1 or M100 may be partially armed as follows if the bomb is to be carried on internal racks:

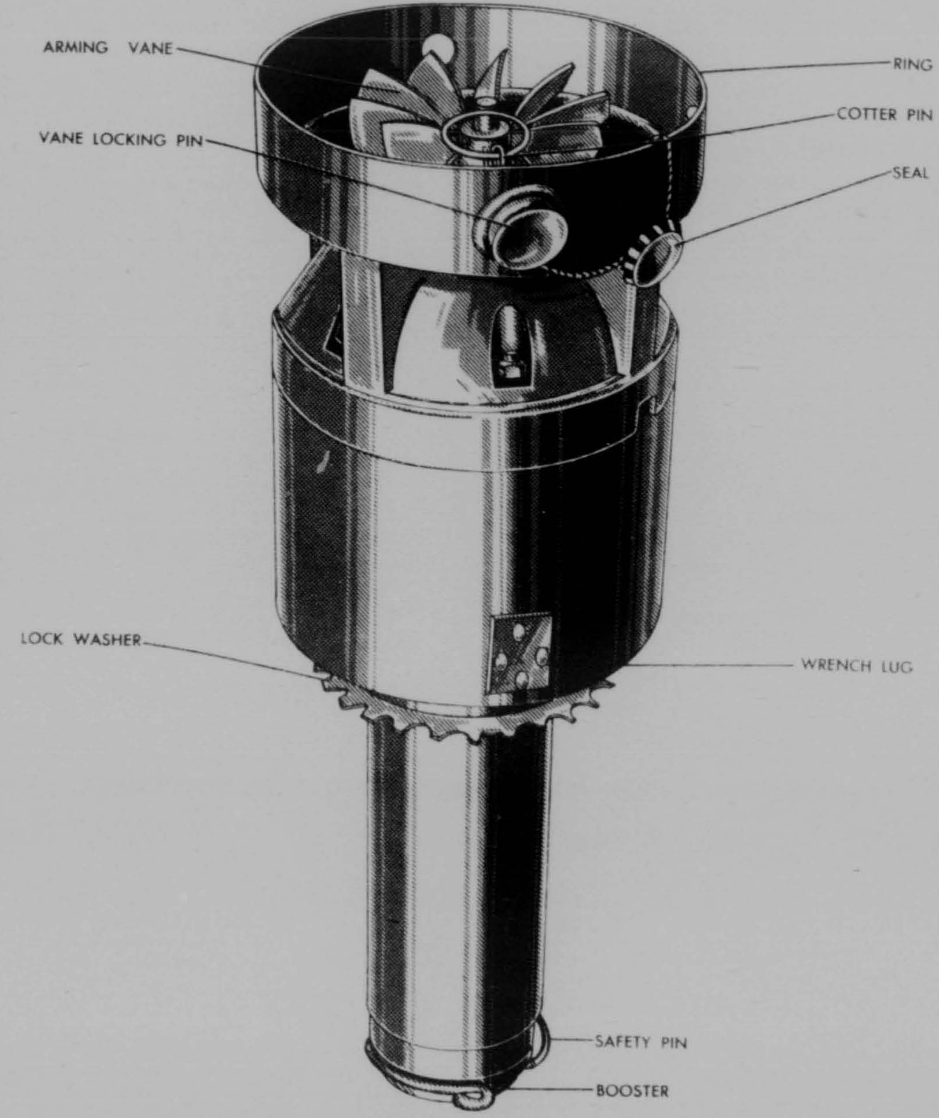

Figure 7—13. Ring-type VT Bomb Fuze.

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The length of the stop rod is measured accurately.

The safety pin is removed and the vane rotated carrier clockwise until the stop rod measures 0.4 inch less than the original measurement. (See below) This should require approximately 350 turns.

Safety pin is replaced and rewired.

A tag attached to seal wire indicating that the fuze is partially armed.

Fuze, bomb, AN-M100A1, or M100, when intended for bombs carried on external racks, will be partially armed as follows:

The seal wire and safety pin are removed. The cotter pin through the body of the fuze is left in place.

The cotter pin through the outer end of the arming stem is removed, then remove the arming head from the stem.

The arming stem is unscrewed (clockwise) from the plunger and removed from the fuze.

The threaded end of the arming stem is shortened 0.4 inch, taking care that all burrs are removed from threads after the cut is made.

The stem is screwed back into plunger until the holes in the stem and stem tube are in register. A pin is placed through the holes until the fuze is assembled.

Arming head is replaced on stem and cotter pin replaced.

The safety pin and seal wire are replaced.

A tag is attached to the seal wire indicating that the fuze is partially armed.

Fuzes partially armed by this method may also be used in bombs carried on internal racks and for purposes where partial arming is not required.

Marking. The fuze is stamped in the metal of the body with the type model and lot number. The sealing wire of the safety pin carries a tag which reads: "Remove pin after arming wire is in place but before attaching arming vane. Replace pin before removing arming wire if bomb is not dropped." In addition to the markings, this fuze is distinguished from the M112, and M123, as follows: the AN-M100A2 has a large arming head and the primer detonator has a single, wide, knurled band. The M112 has a small arming head and the primer detonator has two narrow knurled bands. The M123 is gearless with a direct arming drive.

The body of the fuze has a groove which contains a ball. The primer detonator (Figure 7-11) is marked to indicate the amount of delay.

Packing. Fuze, bomb, AN-M100A2 (tail) is packed, without vane assembly, one per container, 25 containers and 25 vane assemblies, on spindles in a wooden box.

SECTION III—NEW TYPE FUZES—VT BOMB NOSE FUZE, M166 & M168

New Types of Fuzes–VT Bomb Nose Fuze, M166 and M168

The radio-proximity fuze, generally referred to as the VT (variable-time) fuze during its development and combat use, is the perfect example of a "secret weapon." It was kept so for more than four years of development and production, and for more than two years of combat use throughout the world.

VT bomb fuzes produce air bursts on approach to targets such as water, earth, trees, or other objects, including aircraft, either airborne or grounded. No fuze setting is required, except for extended arming distances, when an arming delay is employed.

There are two general types of VT bomb fuzes, ring and bar.

The ring type is characterized by a heavy metallic ring around the arming vane. The M168 fuze is a ring-type VT fuze. Figure 7-13.

The bar type is characterized by metallic bars extending from both sides of the fuze

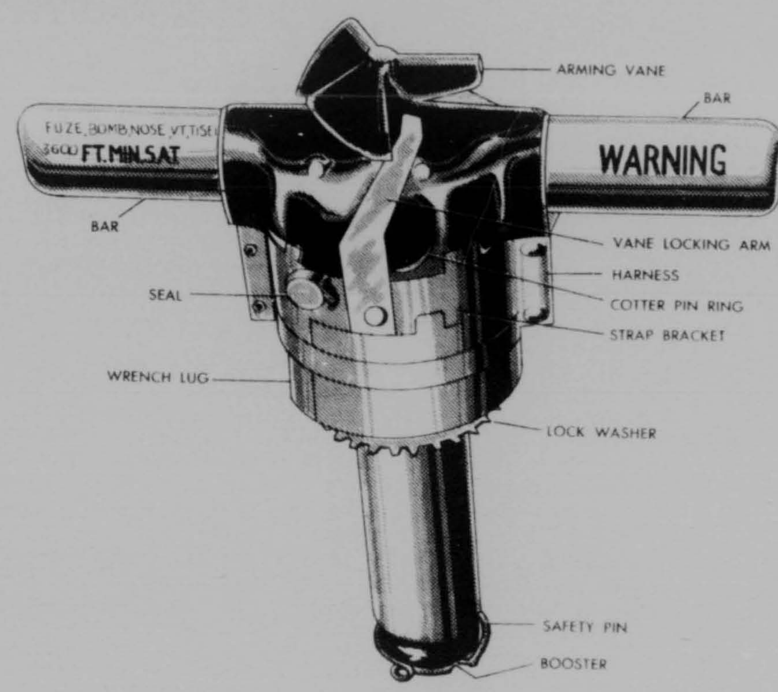

Figure 7—14. Bar-type VT Bomb Fuze.

nose. The M166 fuze is a bar-type fuze. Figure 7-14.

The use of VT bomb fuzes is advantageous in any plane-to-ground application where air bursting the bombs at heights from ten feet to one hundred feet will increase the effectiveness of the operation.

VT bomb fuzes were designed for use in any general-purpose, fragmentation, or chemical bomb weighing one hundred pounds or more which takes the nose fuze AN-M103 or AN-M103A1.

Characteristics of Fuzes

VT bomb fuzes will function automatically as they approach any target of suitable character, thereby causing an airburst to occur at an effective height. (Figure 7-15)

Height of Burst

Ring-type fuzes (M168) produce average heights of bursts from ten to forty feet, depending on the size of bomb, nature of target, altitude of release, and aircraft speed at release. Bar-type fuzes (M166) give heights of burst from forty to sixty feet. They are more nearly independent of bomb size, altitude of release and speed at release than ring-type fuzes. (Figure 7-16)

Effect of target. Figure 7-17. Functioning of all types of VT bomb fuzes is influenced by the character of the target. In the tables of burst-height, the target was assumed to be average dry earth. Over water, or wet earth, the burst height will be higher (approximately 100 per cent higher over water; over dry sand it will be approximately 50 per cent lower). The fuzes are influenced by the gen-

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Model of VT Fuze	Min SAT	Type	Bombs Size (lb)	Safety Pin	Adapted for Arming Delay	Maximum Altitude of Release
M166	3600	Bar	All sizes	Yes	Yes	Unlimited
M168	2000	Ring	100-220 250-260 2000	Yes	Yes	10,000

Figure 7—15. VT Bomb Nose Fuze Data.

eral characteristics of the target area. Dispersed trucks or mud puddles will not affect the height of burst but approach to large, high structures, such as buildings or dense foliage, will cause the fuze to function higher. Ring-type fuzes are more sensitive to passing a target, while bar-type fuzes are most affected by targets directly in their path.

Effect of altitude and speed at release. Ring-type fuzes are affected by the striking angle of the bomb, which depends upon true air speed and altitude at release. This dependence of burst height on release conditions can be used to advantage, since it provides a means of field control over burst height. Bar-type fuzes are relatively independent of striking angles.

Effect of bomb size. The height of burst of VT bomb fuzes is affected to a considerable extent by the size and shape of the bomb. Figure 7-16 lists several bomb and VT fuze combinations and heights of burst which may be expected from each.

Variation in height of burst. Manufacturing variations in component parts and in the fuze assembly lead to a spread in performance so that fuzes do not all burst at the same height under otherwise identical conditions. Figure 7-18 shows the spread in burst height characteristics of the M166 fuze.

BOMB	Fuze M166	Fuze M 168
100-lb GP, AN-M30	60	25
260-lb Frag, AN-M81	60	30
250-lb GP, AN-M57	60	30
500-lb GP, AN-M64	40	20
500-lb GP, AN-M43	40	20
1000-lb GP, AN-M65	40	low
1000-lb GP, AN-M44	40	low
2000-lb GP, AN-M66	45	35
2000-lb GP, AN-M34	25	35
500-lb SAP, AN-M58	40	20
1000-lb SAP, AN-M59	40	low
4000-lb SAP, AN-M56	80	low
325-lb Depth, AN-Mk. 17		25
325-lb Depth, AN-Mk. 44		25
500-lb Incendiary, AN-M76	40	20
500-lb Chemical, AN-M78	40	20
1000-lb Chemical, AN-M79	40	low

Heights of burst are based upon approach of bomb to normal soil at release from 10,000 feet altitude at 200 mph true air speed, except for fuze M168 which was dropped from 8,000 feet altitude. "Low" means the burst occurs from 3 to 10 feet. Blank spaces indicate that no data is available.

Figure 7—16. Burst Height with Various Bomb VT Fuze Combinations (Feet).

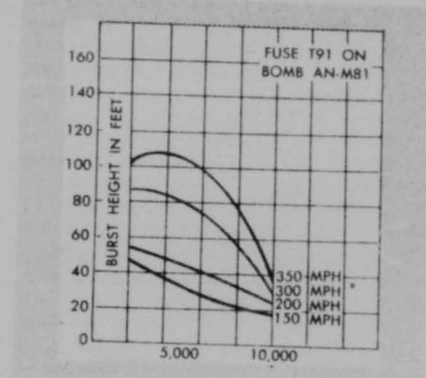

Figure 7—17. Release Altitude in Feet.

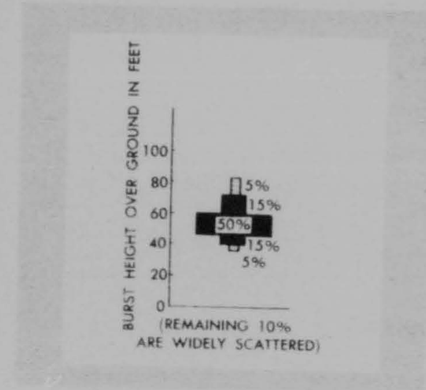

Figure 7—18. Height Dispersion Chart for M-166 Fuze.

Interchangeability

VT bomb fuzes are not operationally interchangeable with the AN-M103, because they are of value only when air bursts are desired. It may be seen in Figure 7-16 that burst height is affected by the physical dimensions of the bomb, particularly with ring-type fuzes.

Reliability

The development of VT bomb fuzes has now reached the point where more than 75 per cent of ring-type fuzes and 85 per cent of bar-type fuzes may be expected to function effectively.

Malfunctions

Malfunctions are of two types: an "early" function and a dud. An early function is a detonation of the VT fuzed bomb at some time after arming has been completed but prior to approach to a target; a dud is a VT bomb fuze which fails to fire.

Early functions. "Earlies" must be expected. The nature of the fuzes does not permit the total elimination of early functions at this time. However an excessive number of earlies (greater than 25 per cent) shows faulty operation and the handling and assembly procedures should be rechecked.

Duds. The effect of dud VT bomb fuzes may be partially compensated by use of a tail fuze of the M100 series in each bomb.

Train spacing. VT fuzes are designed to respond to a sudden change in their surroundings. An armed VT fuze may function due to the bursting of a nearby bomb. This restricts the minimum train spacing that can be used when bombs carry VT fuzes. Since the bursts of larger bombs are more violent, the minimum spacing required is greater for larger bombs. "Armed salvo" and "minimum train" releases will result in an increase in early functions. An intervalometer spacing of 50 feet or more for the 100-pound GP bomb AN-M30 or 260-pound fragmentation bomb AN-M81, or 100 feet or more for the 500-pound GP bomb AN-M64 is satisfactory. When bombs are filled with chemicals the required spacing is less (probably 50 per cent less) than it is for the HE loaded bombs.

Conditions Producing Malfunctions

Improper assembly.
Fin assembly not tight.
Fin assembly bent, damaged, or poorly fabricated.
Fuze damaged.
No lockwasher.
Fuze not tight.
Improper bomb selection.
Insufficient intervalometer spacing.
Rain.
Altitude of release. Too high. Too low.

Rain and Weather

Heavy rain (large drops), clouds, snow, and hail are likely to cause excessive early functions of VT bomb fuzes. Light rain, haze, sunlight, or darkness will not affect them.

Climatic Effects

Full advantage should be taken of the sealed fuze containers, as the unpacked fuzes are likely to deteriorate under warm and humid conditions. Fuzes should be unpacked only when required by the mission at hand.

Altitude and Air Speed at Release

No maximum altitude of release is specified for the M166 fuze. The M168 fuze must be released at altitudes of 10,000 feet or less. However, because of decreased vibration and bearing wear, releases at low altitudes may be expected to yield fewer early functions than releases at high altitudes.

Temperature

VT fuzes have been stored and used at temperatures between —40°F and +140°F without deterioration of fuze performance.

Ballistics

VT bomb fuzes are substantially ballistically interchangeable with bomb nose fuzes AN-M103 or AN-M103A1. Preliminary data available at this time indicate that no special bombing tables are required.

2. SAFETY AND ARMING

General Description of Fuzes

VT bomb fuzes are electric fuzes which develop their energy for proper functioning from a high-speed generator built in the fuze and powered by the arming vane. One of the safety features in these fuzes is an out-of-line electric detonator which is controlled by the arming vane. This detonator remains disconnected from the explosive train and from the detonator firing circuit until completion of arming. As soon as the bomb is dropped and the arming wire withdrawn from the fuze, the arming vane is released and wind stream rotates it at a high velocity. This rotary motion is reduced by a gear-reduction system which rotates the out-of-line detonator into the firing (armed) position and, at the same time, completes the electric circuit to the detonator, thus arming the fuze. The arming vane continues to rotate at a high velocity in order to operate the high-speed generator. The latter supplies current to an electric condenser for firing the electric detonator as soon as the VT fuze is influenced by approach to the target. Unless the condenser has been charged by high-speed operation of the generator, completely-armed VT bomb fuzes are safe to handle if necessary. After the condenser has been charged, sufficient time (sixty minutes) must elapse before an armed VT bomb fuze can be handled safely.

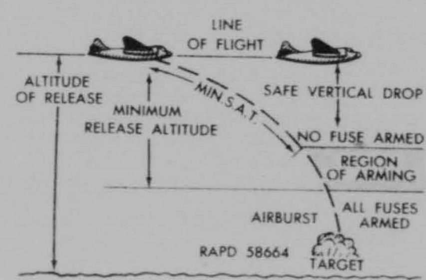

Figure 7—19. Arming—Air Travel—Vertical Drop.

Safe Air Travel

The fact that the arming vane must turn a given number of revolutions (1800 minimum) before the fuze becomes armed means that the bomb must travel a certain distance through the air after the vane is released before the fuze becomes operative. This distance is measured along the trajectory of the bomb and is called safe air travel (abbreviated SAT). Manufacturers' tolerances in parts and assemblies cause variations of a few hundred feet in SAT. Each lot of VT fuzes is tested on the 100-pound GP bomb AN-M30 to evaluate the minimum safe air travel (abbreviated MinSAT) prior to arming, for that lot of fuzes. The MinSAT, that air travel before which no fuze in the lot will arm, is marked on each fuze.

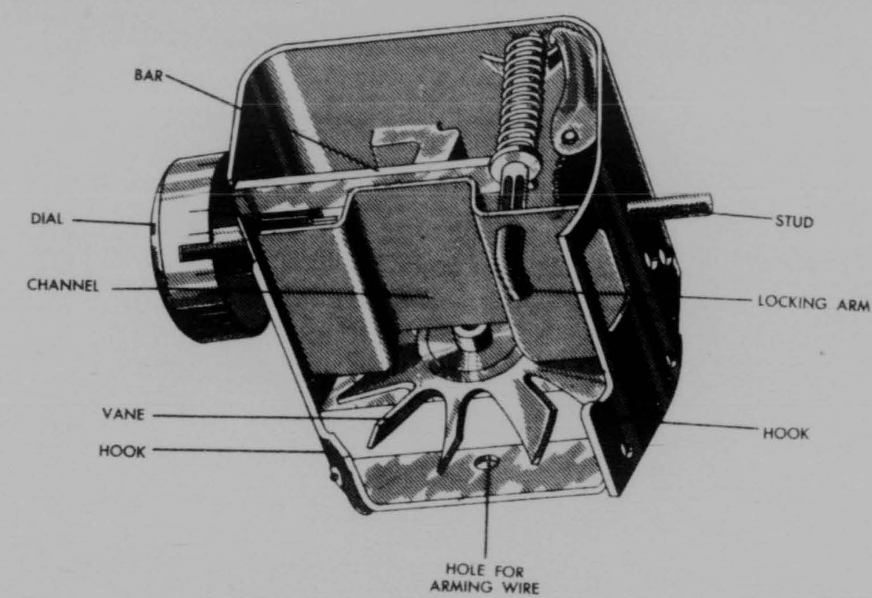

Figure 7—20. Arming Delay Air Travel, T2E1.

Arming Delay, Air Travel, T2E1

For operations which require safe air travel longer than that provided by the MinSAT of the fuze, an arming delay attachment is available for installation on the VT fuze. Arming delay T2E1 is shown in Figure 7-20. It can be used to increase the SAT of the fuze by any amount from 700 feet to about 20,000 feet. The device contains an air vane and a gear reduction system similar to that in the fuze. When the amount of air travel indicated by its dial setting has been traversed, the mechanism disengages itself, flies off the fuze, and releases the vane locking pin in the fuze. At this point, the fuze starts to operate and after a further air travel of the distance marked on it, the fuze is fully armed and operative. **The total safe air travel required to arm the fuze (SAT) is the sum of that of the fuze and that of the arming delay.**

Safe Vertical Drop

Determination of safe vertical drop is of importance from two standpoints:

Safety. It is vitally important that the safe vertical drop prior to arming is sufficient to provide adequate clearance for both the carrying aircraft and any friendly aircraft at lower altitudes. After a VT fuze is armed, it will fire on the first target it approaches, whether it is friendly aircraft, enemy aircraft, or ground targets.

Performance. It is important that the bombs be released at altitudes greater than the safe vertical drop. Otherwise, the VT fuzes will impact in the unarmed condition and they will not function.

Determination of Safe Vertical Drop and Minimum Release Altitude

When VT fuzes are used without arming delay, Figure 7-21 shows the safe vertical drop (SVD) and minimum release altitude (MRA) for each combination of MinSAT, bomb, and true air speed at release. The SVD indicates the vertical drop before which no fuze will arm and the MRA indicates the minimum altitude at which the fuzes should be re-

100-lb GP Bomb AN-M30 250-lb GP Bomb AN-M57 260-lb Frag. Bomb AN-M81

MinSAT Marked on Fuze	150 MPH True air speed SVD ft.	150 MPH MRA ft.	200 MPH True air speed SVD ft.	200 MPH MRA ft.	250 MPH True air speed SVD ft.	250 MPH MRA ft.	300 MPH True air speed SVD ft.	300 MPH MRA ft.	350 MPH True air speed SVD ft.	350 MPH MRA ft.
2000	950	1800	670	1350	450	1000	330	730	250	560
2600	1420	2400	1020	1860	740	1430	560	1060	420	820
3500	2300	3400	1770	2760	1330	2200	1000	1720	770	1350
4500	3100	4350	2500	3650	1960	3000	1500	2400	1200	1930

in

500-lb GP Bomb AN-M-64 1000-lb GP Bomb AN-M65 500 & 1000-lb Chemical Bombs

MinSAT Marked on Fuze	150 MPH SVD ft.	150 MPH MRA ft.	200 MPH SVD ft.	200 MPH MRA ft.	250 MPH SVD ft.	250 MPH MRA ft.	300 MPH SVD ft.	300 MPH MRA ft.	350 MPH SVD ft.	350 MPH MRA ft.
2000	1320	2140	950	1650	670	1220	500	920	400	700
2600	1950	2850	1470	2260	1100	1760	800	1350	620	1050
3500	3020	4050	2400	3350	1880	2720	1460	2170	1150	1720
4500	4050	5240	3350	4450	2720	3700	2150	3020	1700	2450

in

2000-lb GP Bomb AN-M66

MinSAT Marked on Fuze	150 MPH SVD ft.	150 MPH MRA ft.	200 MPH SVD ft.	200 MPH MRA ft.	250 MPH SVD ft.	250 MPH MRA ft.	300 MPH SVD ft.	300 MPH MRA ft.	350 MPH SVD ft.	350 MPH MRA ft.
2000	1630	2340	1200	1800	860	1350	620	1020	480	760
2600	2400	3060	1840	2480	1400	1940	1050	1500	800	1200
3500	3050	4400	2470	3660	2360	2950	1900	2400	1500	1940
4500	4850	5600	4100	4750	3360	4000	2720	3300	2200	2700

Figure 7—21. Safe Vertical Drops (SVD) and Minimum Release Altitudes (MRA) for VT Bomb Fuzes.

leased to insure that all are armed prior to impact. The tables are valid only for level flight releases.

When VT fuzes are used with arming delay, Figure 7-22 (A to F) shows for each combination of bomb and true air speed at release, the dial setting to be used on arming delay T2E1, for various release altitudes. The total safe vertical drop is shown for each case. The tables have been so constructed that for each altitude, the fuze is kept unarmed for as much of its fall as possible without the risk of impacting unarmed. The values are true only for level flight.

Safety Provisions

Seal. To insure that fuzes issued for use have the arming mechanism in the safe position, the vane is sealed at the factory to prevent rotation. If upon receipt of fuzes the seal is found to be broken, they should be handled with caution until destroyed or other disposition is made.

Safety Pin. Later models of VT fuzes (M166 and M168) are equipped with a safety pin inserted into the arming mechanism through an opening in the booster cup. An important feature of the safety pin is that fuzes whose seals have been removed can have the arming mechanism checked for safety in the field. This pin must be removed prior to fuzing the bomb. It can be inserted again only if the arming components are in the safe (unarmed) position. The presence of the pin, or the ability to insert the pin, gives visual indication that the fuze is entirely unarmed.

Damaged Fuzes

An unarmed VT fuze cannot fire. Dropping a packaged fuze will normally not injure it. Dropping an unpackaged fuze or a VT-fuzed bomb may injure the fuze but will not render the fuze unsafe. Damaged fuzes should be destroyed. Unarmed VT fuzes cannot fire and are entirely safe to handle and remove from bombs.

100-lb GP Bomb AN-M30 250-lb GP Bomb AN-M57 and 260-lb Frag. Bomb AN-M81

VT Fuzes marked for 2000 and 2600 ft. MinSAT

Minimum Release Altitude	150 mph* Min SVD	150 mph* Dial Setting	200 mph* Min SVD	200 mph* Dial Setting	250 mph* Min SVD	250 mph* Dial Setting	300 mph* Min SVD	300 mph* Dial Setting	350 mph* Min SVD	350 mph* Dial Setting
1,000									460	1
2,000					900	1	970	2	1100	3
3,000	1570	1	1700	2	1500	3	1880	4	1940	5
4,000	2200	2	2300	3	2180	4	2450	5	2400	6
5,000	2900	3	2950	4	2950	5	3500	7	3450	8
6,000	3600	4	3700	5	4200	7	4100	8	4020	9
7,000	4300	5	4960	7	4850	8	4700	9	4600	10
8,000	5750	7	5640	8	5540	9	5350	10	5800	12
9,000	6500	8	6300	9	6200	10	6650	12	6430	13
10,000	7220	9	7080	10	6900	11	7320	13	7060	14
11,000	7960	10	7800	11	7600	12	8000	14	7720	15
12,000	8690	11	8400	12	9000	14	8700	15	9060	17
13,000	9380	12	9250	13	9700	15	9400	16	9730	18
14,000	10100	13	10650	15	10300	16	10650	18	10260	19
15,000	10960	14	11400	16	11050	17	11400	19	10920	20
16,000	11620	15	12100	17	11750	18	12050	20	12300	22
17,000	12350	16	12830	18	12500	19	12800	21	13000	23
18,000	13100	17	13600	19	13200	20	13500	22	13720	24
19,000	13850	18	14300	20	13900	21	14200	23	14410	25
20,000	15330	20	15050	21	15400	23	14950	24	15100	26
21,000	16100	21	15800	22	16150	24	15650	25	15800	27
22,000	16860	22	16550	23	15850	25	17000	27		
23,000	17620	23	17300	24	17500	26				
24,000	18380	24	18050	25	18400	27				
25,000	19100	25	18800	26						

500-lb GP Bomb AN-M64 1000-lb GP Bomb AN-M65

and

VT Fuzes marked for 2000 and 2600 ft. MinSAT

Minimum Release Altitude	150 mph* Min SVD	150 mph* Dial Setting	200 mph* Min SVD	200 mph* Dial Setting	250 mph* Min SVD	250 mph* Dial Setting	300 mph* Min SVD	300 mph* Dial Setting	350 mph* Min SVD	350 mph* Dial Setting
1,000										
2,000									650	1
3,000							850	1	1050	2
4,000			1550	1	1120	1	1880	3	2000	4
5,000	2030	1	2290	2	2350	3	2470	4	2540	5
6,000	2870	2	2970	3	3050	4	3120	5	3140	6
7,000	3650	3	3750	4	3770	5	3790	6	3770	7
8,000	4500	4	4550	5	4530	6	4490	7	4420	8
9,000	5350	5	5480	6	5310	7	5210	8	5100	9
10,000	6200	6	6200	7	6100	8	5970	9	5530	11
11,000	7070	7	7030	8	6900	9	6730	10	7280	12
12,000	7070	7	7870	9	7700	10	7520	11	8040	13
13,000	7940	8	8710	10	8520	11	8320	12	8820	14
14,000	8800	9	9560	11	9360	12	9100	13	9580	15
15,000	9670	10	9560	11	10170	13	9900	14	10300	16
16,000	10550	11	10410	12	11030	14	10700	15	11120	17
17,000	11430	12	11290	13	11850	15	11500	16	11900	18
18,000	12320	13	12140	14	12700	16	12340	17	12710	19
19,000	13200	14	13000	15	13540	17	13150	18	13530	20
20,000	14080	15	13890	16	13540	17	13980	19	14340	21
21,000	14970	16	14750	17	14400	18	14820	20	15160	22
22,000	15800	17	15620	18	15260	19	15660	21	15980	23
23,000	15860	17	16500	19	16130	20	16500	22	16800	24
24,000	16750	18	18560	20	16970	21	17370	23	17620	25
25,000	17650	19	19430	21	17840	22	18200	24	18470	26

*True air speed. NOTE: Do not drop fuze M168 above 10,000 ft. altitude

Figure 7—22A. Safe Vertical Drops (SVD) and Minimum Release Altitudes (MRA) for VT Bomb Fuzes.

Figure 7—22B. Safe Vertical Drops (SVD) and Minimum Release Altitudes (MRA) for VT Bomb Fuzes.

2000-lb GP Bomb AN-M66
and
VT Fuzes marked for 2000 and 2600 ft. MinSAT

Minimum Release Altitude	150 mph* Min. SVD	150 mph* Dial Setting	200 mph* Min. SVD	200 mph* Dial Setting	250 mph* Min. SVD	250 mph* Dial Setting	300 mph* Min. SVD	300 mph* Dial Setting	350 mph* Min. SVD	350 mph* Dial Setting
1,000										
2,000										
3,000							980	1	1180	2
4,000					1300	1	1510	2	1700	3
5,000	2260	1	1720	1	1940	2	2120	3	2260	4
6,000	2260	1	2480	2	2640	3	2770	4	2860	5
7,000	3100	2	3300	3	3400	4	3560	5	3510	6
8,000	4000	3	4150	4	4180	5	4200	6	4900	8
9,000	4920	4	5000	5	5000	6	4980	7	4900	8
10,000	5800	5	5830	6	5840	7	5770	8	6420	10
11,000	6740	6	6760	7	6700	8	6570	9	7200	11
12,000	7670	7	7670	8	7550	9	7400	10	8000	12
13,000	8000	8	8560	9	8420	10	8300	11	8820	13
14,000	8600	8	8560	9	9310	11	9060	12	8820	13
15,000	9530	9	9470	10	10200	12	9950	13	9630	14
16,000	10500	10	10380	11	11120	13	10800	14	10450	15
17,000	11430	11	11300	12	11120	13	11660	15	10450	15
18,000	12360	12	12230	13	12000	14	12540	16	12140	17
19,000	13300	13	13140	14	12880	15	13410	17	13000	18
20,000	13300	13	14090	15	13800	16	13410	17	13970	19
21,000	14240	14	14090	15	14700	17	14310	18	14740	20
22,000	15200	15	15030	16	15630	18	15220	19	15620	21
23,000	16160	16	15950	17	16560	19	16120	20	16500	22
24,000	17100	17	16900	18	16560	19	17030	21	17380	23
25,000	18070	18	17840	19	17470	20	17930	22	18260	24

*True air speed. NOTE: Do not drop fuze M168 above 10,000 ft. altitude.

Figure 7—22C. Safe Vertical Drops (SVD) and Minimum Release Altitudes (MRA) for VT Bomb Fuzes.

100-lb GP Bomb AN-M30 — 250-lb GP Bomb AN-M57 — 260-lb Frag. Bomb AN-M81
and
VT Fuzes marked for 3600 and 4500 ft. MinSAT

Minimum Release Altitude	150 MPH* Min. SVD	150 MPH* Dial Setting 3600 SAT	150 MPH* Dial Setting 4500 SAT	200 MPH* Min. SVD	200 MPH* Dial Setting 3600 SAT	200 MPH* Dial Setting 4500 SAT	250 MPH* Min. SVD	250 MPH* Dial Setting 3600 SAT	250 MPH* Dial Setting 4500 SAT	300 MPH* Min. SVD	300 MPH* Dial Setting 3600 SAT	300 MPH* Dial Setting 4500 SAT	350 MPH* Min. SVD	350 MPH* Dial Setting 3600 SAT	350 MPH* Dial Setting 4500 SAT
6,000				2800	3	1	2800	4	2	3100	5	4	3000	6	5
7,000	3500	3	1	3400	4	2	3700	5	4	3500	6	5	3600	8	6
8,000	4100	4	2	4400	5	4	4300	6	5	4100	7	6	4500	9	8
9,000	4800	5	3	5000	6	5	4900	7	6	4800	9	7	5000	10	9
10,000	5800	6	5	5700	7	6	5400	8	7	5800	10	9	5500	11	10
11,000	6600	7	6	6300	8	7	6300	10	8	6400	11	10	6300	13	11
12,000	7100	8	7	6900	9	8	7300	11	10	7000	12	11	6700	14	12
13,000	7800	9	8	7600	10	9	7900	12	11	7500	13	12	7700	15	14
14,000	8500	10	9	8400	12	10	8500	13	12	8300	15	13	8300	16	15
15,000	9100	11	10	9000	13	11	9100	14	13	9300	16	15	9000	18	16
16,000	9800	12	11	9700	14	12	9700	15	14	9900	17	16	9700	19	17
17,000	10400	13	12	10300	15	13	10300	16	15	10400	18	17	10300	20	18
18,000	11300	15	13	11400	16	15	11200	18	16	11200	19	18	11300	21	20
19,000	11900	16	14	12100	17	16	11800	19	17	11800	20	19	11900	22	21
20,000	12600	17	15	12600	18	17	12500	20	18	12400	21	20	12500	23	22
21,000	13300	18	16	13400	19	18	13600	21	20	13200	23	21	13100	24	23
22,000	13900	19	17	14000	20	19	14200	22	21	13900	24	22	14000	26	24
23,000	14500	20	18	14700	21	20	14900	23	22	14500	25	23	14600	27	25
24,000	15300	21	19	15300	22	21	15500	24	23	15600	26	25	15200		26
25,000	16400	22	21	16000	23	22	16200	25	24	16300	27	26			

*True air speed. SAT figures are minimum and are in feet.

Figure 7—22D. Safe Vertical Drops (SVD) and Minimum Release Altitudes (MRA) for VT Bomb Fuzes.

500-lb GP Bomb AN-M64, 1000-lb GP Bomb AN-M65, 500-lb and 1000-lb Chemical Bombs
and
VT FUZES marked for 3600 and 4500 ft. MinSAT

Minimum Release Altitude	150 MPH* Min. SVD	150 MPH* Dial Setting 3600 SAT	150 MPH* Dial Setting 4500 SAT	200 MPH* Min. SVD	200 MPH* Dial Setting 3600 SAT	200 MPH* Dial Setting 4500 SAT	250 MPH* Min. SVD	250 MPH* Dial Setting 3600 SAT	250 MPH* Dial Setting 4500 SAT	300 MPH* Min. SVD	300 MPH* Dial Setting 3600 SAT	300 MPH* Dial Setting 4500 SAT	350 MPH* Min. SVD	350 MPH* Dial Setting 3600 SAT	350 MPH* Dial Setting 4500 SAT
6,000							3500	3	2	3500	4	3	3500	5	4
7,000				4300	3	2	4200	4	3	4100	5	4	4100	6	5
8,000	4500	3	1	4500	4	2	4900	5	4	4800	6	5	4700	7	6
9,000	5300	4	2	5200	5	3	5700	6	5	5500	7	6	5600	9	7
10,000	6100	5	3	6100	6	4	5400	7	6	6200	8	7	6600	10	8
11,000	6900	6	4	6800	7	5	7100	8	7	6900	9	8	6900	11	9
12,000	7700	7	5	7000	8	6	7400	9	7	7500	10	9	7500	12	10
13,000	8200	7	6	8400	9	7	8600	10	9	8300	11	10	8200	13	11
14,000	9100	8	7	9200	10	8	9400	11	10	9100	12	11	9030	14	12
15,000	9900	9	8	9700	10	9	9700	12	10	9930	13	12	10200	15	14
16,000	10700	10	9	10500	11	10	10400	13	11	10600	14	13	10400	16	14
17,000	11500	11	10	11340	12	11	11200	14	12	11400	15	14	11200	17	15
18,000	12300	12	11	12100	13	12	12100	15	13	12100	16	15	11800	18	16
19,000	12600	13	11	12900	14	13	12800	16	14	12900	17	16	12500	19	17
20,000	13400	14	12	13700	15	14	13300	15	15	13500	18	17	13300	20	18
21,000	14300	15	13	14500	16	15	14100	17	16	14400	19	18	14200	21	19
22,000	14800	15	14	15400	17	16	14900	18	17	15300	20	19	15000	22	20
23,000	15600	16	15	15500	18	16	15700	19	18	15900	21	20	15500	23	21
24,000	16500	17	16	16400	19	17	17300	20	19	16800	22	21	16400	24	22
25,000	17300	18	17	17200	20	18	15900	21	20	17000	23	21	17200	25	23

*True air speed. SAT figures are minimum and are in feet.

Figure 7—22E. Safe Vertical Drops (SVD) and Minimum Release Altitudes (MRA) for VT Bomb Fuzes.

2000-lb GP Bomb AN-M66
and
VT Fuzes marked for 3600 and 4500 ft. MinSAT

Minimum Release Altitude	150 MPH* Min. SVD	150 MPH* Dial Setting 3600 SAT	150 MPH* Dial Setting 4500 SAT	200 MPH* Min. SVD	200 MPH* Dial Setting 3600 SAT	200 MPH* Dial Setting 4500 SAT	250 MPH* Min. SVD	250 MPH* Dial Setting 3600 SAT	250 MPH* Dial Setting 4500 SAT	300 MPH* Min. SVD	300 MPH* Dial Setting 3600 SAT	300 MPH* Dial Setting 4500 SAT	350 MPH* Min. SVD	350 MPH* Dial Setting 3600 SAT	350 MPH* Dial Setting 4500 SAT
6,000							3600	2	1	3600	3	2	3600	4	3
7,000				4300	2	1	4400	3	2	4300	4	3	4300	5	4
8,000				4600	3	1	4700	4	2	5100	5	4	5000	6	5
9,000	5400	3	1	5500	4	2	5400	5	3	5900	6	5	5800	7	6
10,000	6000	3	2	6100	4	3	6300	6	4	6700	7	6	6600	8	7
11,000	6900	4	3	7000	5	4	7300	7	5	7000	8	6	7300	9	8
12,000	7900	5	4	7800	6	5	7800	7	6	7800	9	7	8100	10	9
13,000	8800	6	5	8800	7	6	8500	8	7	8600	10	8	9000	11	10
14,000	9700	7	6	9700	8	7	9500	9	8	9000	11	9	9900	12	11
15,000	10100	8	6	10600	9	8	10400	[illegible]	9	10100	11	10	10700	13	12
16,000	11100	9	7	10800	10	8	11300	11	10	11000	12	11	11600	14	13
17,000	11600	9	8	11900	11	9	12200	12	11	11900	13	12	11800	15	13
18,000	12600	10	9	12500	11	10	12400	13	11	12800	14	13	12600	16	14
19,000	13500	11	10	13400	12	11	13400	14	12	13700	15	14	13900	17	15
20,000	14500	12	11	14400	13	12	14100	14	13	14500	16	15	14800	18	16
21,000	14700	13	11	15400	14	13	15000	15	14	15400	17	16	14900	18	17
22,000	15700	14	12	16300	15	14	15500	16	15	15700	18	16	15800	19	18
23,000	16500	14	13	16500	16	14	16800	17	16	16600	19	17	16700	20	19
24,000	17500	15	14	17300	17	15	17700	18	17	17500	20	18	17600	21	20
25,000	18000	16	15	18000	17	16	18800	19	18	18500	21	19	18500	22	21

* True air speed. SAT figures are minimum and are in feet.

Figure 7—22F. Safe Vertical Drops (SVD) and Minimum Release Altitudes (MRA) for VT Bomb Fuzes.

An undamaged VT fuze will not fire unless the vane is turning rapidly (2000 rpm or more), even though it is armed. If the fuze is intact and the vane is not turning, it is safe to handle, except as noted below.

An armed VT fuze, damaged while the vane was turning at high speed, is dangerous. It should not be handled until after sixty minutes when it will be safe for necessary disposal. Before that time it may be sensitive to shock, jar, or approach.

An unarmed VT bomb fuze, even though severely damaged, should be safe. A fuze which becomes damaged when leaving the aircraft would most probably damage the arming vane and never arm. Approximately 2000 revolutions of the vane are required to arm a 2000 foot MinSAT fuze. A larger number of revolutions is required for fuzes with a greater value of MinSAT.

A VT fuze dropped from altitudes below the safe distances will function only in exceptional circumstances. Each lot of fuzes is checked against this in the acceptance test. The tail fuze, having a shorter arming distance, will govern the safety in such an instance.

3. FUNCTIONING

Released to Arm

When a VT-fuzed bomb is released armed, the arming wire is retained in the bomb shackle.

With No Arming Delay. As the bomb falls away, the arming wire is pulled from the vane locking arm (or pin) permitting the pin to be thrust away from the fuze by its spring, thereby releasing the arming vane. The wind stream turns the arming vane which arms the fuze after the bomb has traveled the distance specified as the MinSAT of the fuze. The armed fuze will fire upon approach to a target.

With Arming Delay. As the bomb falls away, the arming wire is pulled from the arming delay and vane locking arm (or pin). The wind stream spins the vane of the arming delay until the bomb has traveled the distance corresponding to the dial setting of the arming delay. At that point the arming delay disengages itself and flies off, releasing the vane locking arm (or pin), permitting the arming vane on the fuze to spin. From that point, the fuze begins to arm as explained above and having completed its arming, will fire upon approach to a target.

Released Safe

When a VT-fuzed bomb is released safe, the arming wire is disengaged from the bomb shackle and falls with the bomb. Since the arming wire does not release either the vane of the arming delay (if the arming delay is attached), or the vane locking arm (or pin), the fuze does not arm, and will impact in an unarmed condition. An unarmed VT fuze will not detonate upon impact, and may be dropped safe under any conditions permitted by the particular bomb in which it is assembled.

4. TESTING IN THE FIELD

Field Testing

No testing of VT bomb fuzes is possible in the field, except by dropping them in the bombs for which they are designed. Fuze lots may be checked for operational efficiency by dropping a representative sample of each lot. The samples should be taken from as many different boxes as possible.

Test Conditions

Tests should be conducted over water or level terrain if possible, in order to assess fuze performance under uniform conditions. Heights of burst over water will be about double those obtained over normal soil.

5. ASSEMBLING VT FUZES TO BOMBS

General

VT bomb fuzes are shipped to the field completely assembled, ready for installation in the bomb. Field assembly consists of installing the fuze in the bomb and, if tactics require it, adding an arming delay. It is recommended that wherever possible, the assembly operation be performed after the bombs are loaded into the bomb bay. In this case, care must be exercised to insure that the fuzes are assem-

bled sufficiently tight without causing damage to the bomb shackles. Where assembly in the bomb bay is impossible, or inconvenient, and regulations permit, the assembly may be performed with safety before the bombs are loaded.

Inspection

In inspecting the bomb assembly, no bombs having bent or damaged fins are used. Fin assemblies must be as tight as possible. The fuze well must be free of dirt, rust, or other foreign material. One also must inspect the fuze to insure that the vane and vane locking arm (or pin) is not damaged. If sealing wire is broken or missing, the fuze must not be used. It must be handled carefully until destroyed or safe disposition can be determined.

To Assemble Fuze

One removes the safety pin, if there is one, from the fuze booster.

The fuze is screwed into the nose fuze well of the bomb, by hand. The lockwasher must be in place.

The fuze is tightened as much as possible by applying fuze wrench T4 to the fuze lugs. If this wrench is not available another type may be used. Never hammer fuze or wrench handle, nor use bars of bar type fuzes as levers or handles. The bars should not be struck or twisted in any manner.

The sealing wire is cut and removed.

The vane locking pin or arm is moved to the hole in the ring (ring-type fuzes) or strap bracket (bar-type fuzes) nearest in line with the bomb suspension lugs. The arming vane should not be turned more than two or three turns during this operation.

To Assemble Arming Delay to Fuze

Preparation. The delay is placed on a flat surface, vane down, dial to right. The dial is freed by pressing the short projecting stud on left face down and outward. Holding the bar across the top of the arming delay down, the dial is turned until bar is in line with slot in dial. The bar is released carefully to avoid injury from spring action.

Assembly. The short end of the arming wire is threaded through the front suspension lug through the small hole in the strap on the vane end of the arming delay and through the hole in the vane locking arm (or pin) where the seal wire was.

The arming delay is placed with its vane-end toward the bomb tail, so that the channel is over the vane locking arm (or pin) and the hooks of the arming delay engage the bottom of the fuze ring or strap bracket.

The bar is turned back in place through the slot in the dial.

The stud is pressed as before, and the dial turned to the desired setting.

The arming wire is adjusted to protrude two or three inches in front of the fuze nose. A safety (fahnestock) clip is never used. The force of the spring, after the cotter pin has been removed, is sufficient to hold the arming wire firmly in place.

The cotter pin is removed.

To Assemble Arming Wire (When Arming Delay Is Not Used)

The short end of the arming wire is threaded through the front suspension lug and through the hole in the vane locking pin (or arm) where the seal wire was.

The arming wire is adjusted to protrude two or three inches in front of the fuze nose. A safety (fahnestock) clip is never used. The force of the spring, after the cotter pin has been removed, is sufficient to hold the arming wire firmly in place.

The cotter pin is removed.

Tail Fuze

A tail fuze of the M100 series (instantaneous) should be used as insurance for bomb detonation on ground impact in case the VT fuze is a dud. Testing assembling, and attachment of arming wire should follow normal procedure for the fuze employed.

Caution

Care should be exercised with bar type fuzes to make certain that those on the bottom station have bars oriented horizontally. Otherwise, in some instances, the fuzes will be damaged when the bomb bay doors are closed.

6. TO REMOVE VT FUZES FROM BOMBS

General

If the plane returns with its bombs, and when use of the fuzed bombs within forty-eight hours is unlikely, the fuzes should be removed from the bombs, returned to their containers, and sealed as tightly as possible.

To Remove Fuze

Cotter pin is replaced in the vane locking pin (or arm).

If arming delay is present it is removed by pressing the stud toward the fuze. Holding bar across open end, the dial is turned until the dial slot is in line with the bar. Arming delay is released by sliding it back along the arming wire.

Arming wire is pulled from vane locking arm (or pin).

Sealing wire is inserted through hole vacated by arming wire, and ends are twisted around ring or harness strap.

The fuze is loosened with fuze wrench T4 until it may be removed by hand. If the fuze has not been assembled tightly, removal of the fuze may be facilitated by first flattening lockwasher by further tightening of the fuze.

Fuze is removed from fuze well. Lockwasher must not be lost and is kept with fuze.

Safety pin is replaced through booster cup if fuze was equipped with safety pin.

Fuze is replaced in container. Container is resealed as tightly as possible.

Disassembly of Fuzes

VT bomb fuzes must not be disassembled under any condition.

SECTION IV—ROCKETS & RELATED FUZES

1. HISTORICAL HIGHLIGHTS IN ROCKET DEVELOPMENT

Chinese and Arabs in the thirteenth and fourteenth centuries attached gun powder to fire arrows which had been used for a long time. The fire arrows had been used as incendiaries by attaching masses of pitch, tar, and oil-soaked rags. They were ignited just prior to firing from bows. With the addition of the gun powder in paper cases, the arrows became self-propelled when ignited.

The first notable military use of rockets was in India at the end of the eighteenth century when the princes of Mysore defended their towns against siege by the British with as many as five thousand flames-throwing rockets. Although the British captured the town despite this unusual defense, the latter saw the need for experimentation in the military use of rockets. Most notable of the early British experimenters was William Congreve who succeeded in perfecting several rockets suitable for military operations.

In 1805, the British dispatched special rocket boats against the French seacoast town of Boulogne. Rough weather prevented their use on this occasion but the following year considerable damage was done to the town and military stores by many fires caused by flames of two hundred rockets fired from eighteen boats. The rockets were fired in half an hour from a distance about half a mile.

In the latter part of the nineteenth century, with the advent of rifling breech loading, recoil mechanisms, smokeless powder and advancement in metallurgy, rockets were discontinued in warfare. At the turn of the present century, Britain declared rockets obsolete for military use, when after a fire in Woolwich Arsenal, considerable stores of rockets were destroyed without a single loss of life. It was considered that so great a loss of military

stores could not produce such inconceivable lack of injury and loss of life, if rockets had any military value.

During the years 1939 to 1941, the British produced some good antiaircraft rockets. The British rockets stimulated interest in this country and our rockets were patterned after those of the English. Meanwhile, the Germans had collected extensive material on rocket research which had been taken over by the German Army in 1935. By the start of the war, they had developed many types of offensive and defensive rockets. The use of aircraft rockets by German aircraft was finally responsible for the discontinuance of daylight bombing without fighter escort. Ironically, much of the early information which started the Germans on their intense rocket research, came from the experiments and achievements of an American inventor and scientist, Dr. Robert Hutchings Goddard, whose great work went unrecognized here in the United States in the peaceful years that followed WW I.

2. USES OF ROCKETS IN MODERN WARFARE

The earliest practical use of rockets was in the field of communications. It was found that rockets were especially valuable at night as a distress signal at sea, because the rockets were visible at considerable distance. By taking a bearing on the source of the rocket trajectory, rescue boats were able to save a great number of lives of those drifting helplessly at sea.

Since rockets could be illuminated with several different colors, it was possible to use rockets as signals to convey messages. Consequently, colored rockets found much use both in war and peace as signals and a means of communication, especially on the sea at night, or on the battlefield. By the use of various color combinations, many simple messages could be conveyed quickly over several miles distance.

A later use of rockets was in the pyrotechnic field to assist planes in locating an airport that was closed in by the weather or poorly lighted at night. Flares attached to the rockets, or star clusters, which burst at the highest point in the rocket's vertical flight, were visible to planes at considerable distance from the air field. By following the light of the flares or rocket bursts, which were sent up at regular intervals, lost planes could soon locate the airport. At present, this use of rockets is practically obsolete due to advances made in navigation and instrument landings.

Still another use of rockets was at sea to convey a line or rope from land to a foundering boat or from one boat to another. A light line would be attached to the rocket which would be made to pass low over the foundering boat. When the rocket dropped in the sea, the light line dropped across the deck of the vessel and was used to pull in a heavy rope for towing purposes, or to pull in a cable for transferring passengers by means of a breeches buoy.

The military use of present day rockets is well known. Aircraft rockets have the same effective action as projectiles from 155-mm guns and are very useful against many military targets such as locomotives, tanks, vehicles, planes, buildings, boats, gun emplacements, and harbor installations, as well as against enemy aircraft both in the air and on the ground.

The latest use of aircraft rockets has been in research of the upper air. Rockets have been sent up to a height of 114 miles and it is expected they will go much higher. Within the head of these rockets, is placed a container of many delicate scientific instruments. At the rocket's extreme height the instrument container is jettisoned and brought to earth gently by means of two parachutes, one of which is a small one that opens at the highest altitude; the other a larger one that opens at a lower altitude usually about twenty-eight miles. The point at which the instruments drop to earth is located by means of radar and a helicopter. Data from the weather instruments is being used in long range weather forecasting. Other data aids in the design of future stratosphere supersonic or even hypersonic aircraft.

3. ADVANTAGES OF AIRCRAFT ROCKETS

The use of aircraft rockets has expanded at an incredible rate. In the year 1945, the year of greatest production, the Navy alone was spending as much as $100,000,000 a month for rocket ammunition. The use of rocket ammunition became automatic for amphibious landings after just a few trials. The reason for this sudden expansion was due to the fundamental advantages of the rocket over artillery.

In the airplane, the aircraft rocket had far greater range than the heaviest gun that the aircraft could carry without major modifications. The trajectory was flatter for aircraft rockets than ground rockets due to the speed of the plane added to the initial speed of the rocket. Consequently, the accuracy was exceptionally good. The principle of reaction by which rockets are impelled, brings about a third definite advantage, namely lack of recoil of the mount or launcher. The consequence to this is no shock of firing to the airplane and a very light launching apparatus may be used. As a direct result, the load on the airplane is much less than if a heavy gun mount had to be carried. Although, at present only a few sizes of rockets are used, a wide range of rocket sizes is feasible on aircraft. The gentle takeoff of a rocket allows high-powered, but more sensitive, explosives to be used. Other advantages are the high speed and range of larger rockets which makes interception and countermeasures a difficult problem. Also, small rockets are adaptable to the use of space charges which make possible extremely great penetration power despite the slower speed of the rocket. Still another advantage is that rockets have made possible research into the ionosphere or upper air at higher altitude than ever before attained by man. Stepped rockets show promise of even going much higher and are theoretically capable of velocities great enough to leave the gravitational field of the earth into interplanetary space at hypersonic speeds of 5000 or more miles per hour.

4. LIMITATIONS OF AIRCRAFT ROCKETS

Temperature Limitations

Rockets such as the 4.5" M8A3 rocket have operating limits set at 10°F and 105°F. Other rockets operate from 0°F to 120°F and from 40°F to 120°F. However, by special procedure and added safety measures, it is possible to fire between limits, 40°F and 140°F. Below and above these temperatures present military propellants can not be used with dependability or safety. Certain test rockets are being designed for greater temperature range.

Accuracy Limitations

Rockets do not have the accuracy at longer ranges of artillery where destruction of a specific target is required. However, they are ideal against area targets because many launchers can be assembled rapidly at one point and fired at a high rate of fire with great destructive result. When accuracy can be sacrificed for time, that is when ability to fire any ammunition is more important than the accuracy, or when fired at relatively short ranges, rockets are the ideal military weapon for high destructive power.

Efficiency Limitations

Rocket missiles are not as efficient as artillery projectiles because they are heavier than a shell of equal explosive weight, owing to carrying the propellent charge and burned-out motor tube through the air as dead weight, and fragmenting it at the target. However, when overall weight is considered, the rocket compares favorably. For example, the 4.5 rocket and launcher weighs 55 pounds total compared to 4000 pounds for the 105-mm howitzer of about equal fire power. On the other hand, rockets of the same caliber as artillery, in general, have the lesser range.

Disadvantage of Blast

The blast from a rocket jet endangers personnel and equipment near the launcher. It is important that nothing be in the way of the tremendous rear blast of the intensely-hot, propellent gases for at least the danger distances published in the instructions for each rocket. Aircraft in formation must observe these rules when firing to prevent possible damage to a following friendly aircraft.

Hazards of Manufacture, Transportation, and Storage

In general, rocket propellants are somewhat more dangerous than other propellants

to manufacture. Solid propellents often have to be made by the solventless process or dry method which is more dangerous than the solvent method used for making the ordinary smokeless-powder propellents. Transportation and storage are also more dangerous due to the fire hazard and sensitive nature of rocket fuels which cannot withstand the shock of rough handling. Since more sensitive explosives can be used in the war head of rockets, storage of these is more dangerous. Some of the liquid fuels, such as liquid hydrogen and various hydrocarbons used, present special storage problems. Oxidizing agents such as liquid oxygen and hydrogen peroxide are dangerous to handle and store. Fortunately, most of these agents are not used in aircraft rockets.

5. BASIC PRINCIPLES OF ROCKET FLIGHT

Newton's Third Law of Motion

The principle upon which rocket flight depends was stated by Sir Isaac Newton in 1679, namely: To every action there is always an equal and opposite reaction. An example of Newton's third law of motion is the kick of a rifle. The momentum or mass X velocity, MV of the bullet is equal and opposite to the momentum MV of the rifle. This is understandable when one realizes that the velocity of the bullet is high but its mass or weight is low, whereas the weight of the rifle is high in comparison to that of the bullet. The momentum not taken up in the acceleration of the rifle is resisted by the thrust against the shoulder of the person firing. Another example, more typical of the reaction in a rocket, is that of a rapidly deflating, free to move, rubber balloon.

6. IDEAL PROPELLANTS AND GENERAL REQUIREMENTS OF ROCKET PROPELLANTS

There are two delicately-balanced factors which are closely related to the movement of a rocket; first, the burning of the powder tending to increase pressure within the rocket, and second, the escape of gases tending to reduce the pressure within the rocket. These factors are influenced by the composition of the powder, shape of grains and rate of burning as well as features of the rocket design. In order to gain the most desirable results, **an ideal propellant for rockets would have the following characteristics:**

Ignite and burn uniformly at low pressure.

Have a well-defined reproducible and approximately constant burning surface.

Nonhygroscopic.

Procurable in grains having burning times variable through wide limits.

Possess adequate mechanical properties.
Smokeless.
Flashless.
Stable.
Not affected by temperature variations.

Another general requirement of rocket powder is that the grains be much larger than those of artillery powders to make for ease of mounting in the motor tubes and on trap assemblies. The powder should also be somewhat slower burning than artillery powders. The large grains require a solventless or dry manufacturing process rather than the wet or solvent process because of the long drying times and warpage which occurred in the latter process. No one powder could satisfy all these characteristics and general requirements, but double base powders have proved quite satisfactory.

7. FUNCTION OF PROPELLANT COMPONENTS

The plasticizer is used as a bond. The opacifier absorbs heat of radiation, preventing rapid decomposition within the powder by the heat. This decomposition would eventually cause an internal powder pressure which would cause breakage of the grain. The stabilizer absorbs gaseous products of slow decomposition and generally reduces hygroscopicity or tendency to absorb moisture. The flash depressor works its result by cooling of powder gases. The grain is made in cruciform, or cross shaped section. A portion of the surface of the grain is covered with fire resistant plastic strips which are inert and act as inhibitors preventing the burning surface from becoming too great which would increase the burning rate above the desired limits. In some rockets, the grains are cylindrical, perforated at the center to prevent degressive burning and so that they can be supported on wires threaded through the central hole. The support for the grains is known as a grid or trap assembly.

8. EFFECTS AND ADJUSTMENTS FOR TEMPERATURE

High ambient temperatures increase the burning rate. In certain rockets, the powder charge is reduced when the surrounding temperature is too high. This adjustment reduces the range, but does not appreciably affect the velocity of the rocket during burning time. In other rockets, an additional central nozzle is plugged with a thin metal disc which blows out at high temperatures and pressure, causing a reduction in internal pressure, allowing the rocket to function without harm at high ambient temperatures. Low ambient temperatures increase the chances of failure to ignite and also cause "chuffing" which is the extinguishment of burning for a brief period and then reignition, causing the rocket to go on a haphazard trajectory; low temperatures also cause condensation of moisture within the rocket which tends to cause an increase in hygroscopicity and temporary slowing of the burning rate. The only adjustment for low temperature is to use a different composition powder which is suitable for these requirements. The temperature range of newest propellants is from 40°F to 140°F.

9. STABILITY OF ROCKET FLIGHT AND ACCURACY

Rotation

Rocket launchers, unlike guns of artillery, have no rifling and consequently do not impart rotation to the rocket. Fins may be attached to the rear of the motor body to obtain stability; such rockets are called fin-stabilized rockets. In other rockets, a ring of nozzles may be used instead of a single central nozzle, each separate nozzle being canted sidewise so that the passage of the propellent gases through them imparts rotation to the rocket; such rockets are called spin-stabilized rockets. Fin-stabilized rockets might rotate slowly because of some irregularities of the fin construction but no induced rotation is intended. Spin-stabilized rockets are more accurate than fin-stabilized rockets because malalignment of the jet is unimportant since the rapid spin tends to average out its effects and the absence of fins eliminates drag. A fin-stabilized rocket of 4.5 inches, such as the M8 type, has $1\frac{1}{2}$ times the dispersion of the spinner type rocket M16 of 4.5 inch size. Rockets fired from aircraft with increased linear velocity require also an increased angular velocity or stability will be reduced.

Effect of Wind

The accuracy of rockets is obviously improved by firing them from aircraft in the same direction as the plane's flight, because the rocket has the added velocity of the plane as a component. Furthermore, there is a tendency of the rocket to turn into the wind. Consequently they should be fired either against the wind or with the wind, but not cross wind or from the plane during a turn, which has the same effect on the rocket's accuracy. Slight winds up to thirty miles per hour may be compensated for by windage adjustments on the sight without decrease in accuracy. Rockets fired from aircraft have from one-fifth to one-third the dispersion of rockets fired on the ground, depending on the speed of the aircraft from which they are fired. It must be noted, also, that upper winds do not have the same velocity and direction as surface winds. All wind corrections for rockets and bombs are based on the wind effect at a definite-speed dive angle and slant range. It has been stated, contrary to general belief, that cross-wind dives give as great an accuracy as up-wind or down-wind dives when only one type of projectile is used. Using combinations of weapons the up-wind and down-wind dives are better; the wind effect is proportional to the sine of the angle of dive times the velocity of the wind at the release altitude. This means that for each angle of dive the 90 degree cross-wind effect remains relatively fixed. Head winds, tail winds, or target movements are proportional to the cross-wind effect times the sine of the angle of dive.

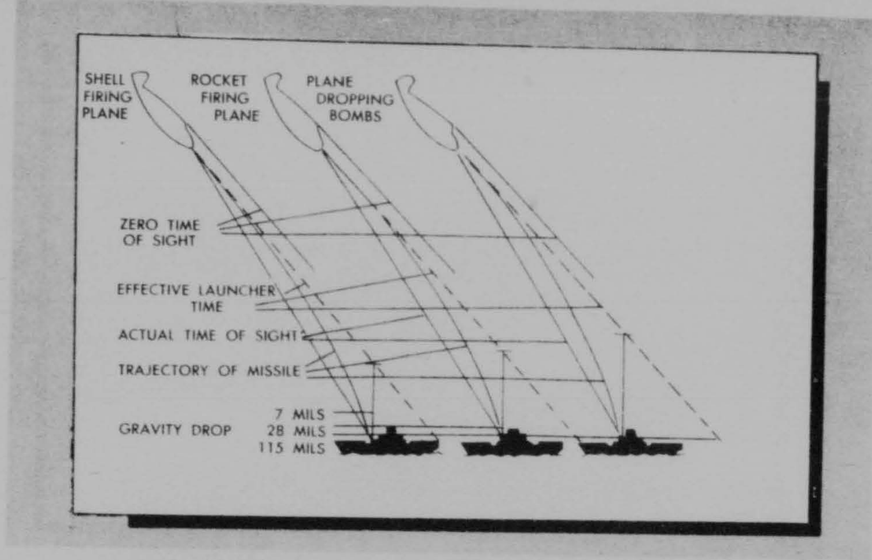

Figure 7—23. Typical Rocket Trajectory Vs. Trajectories of Shell and Bomb.

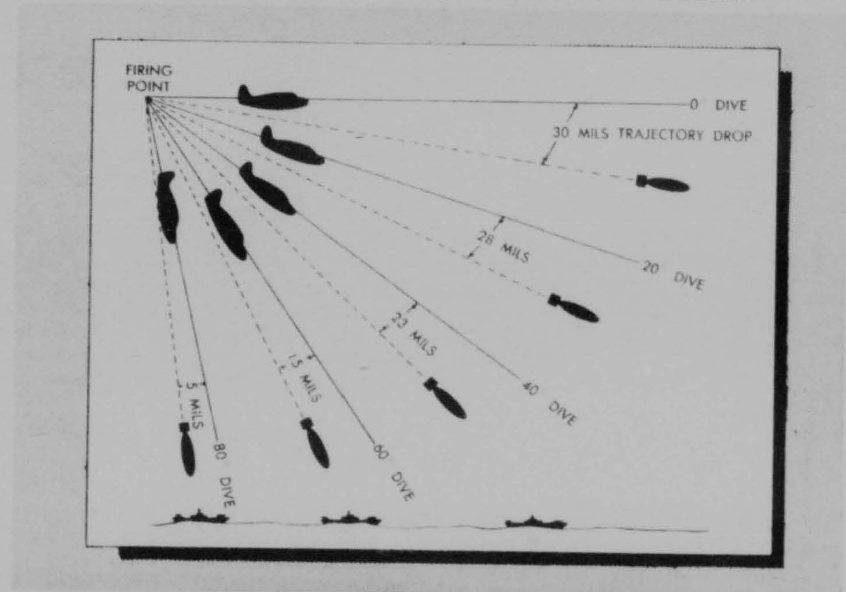

Figure 7—24. Effect of Dive on Trajectory Drop.

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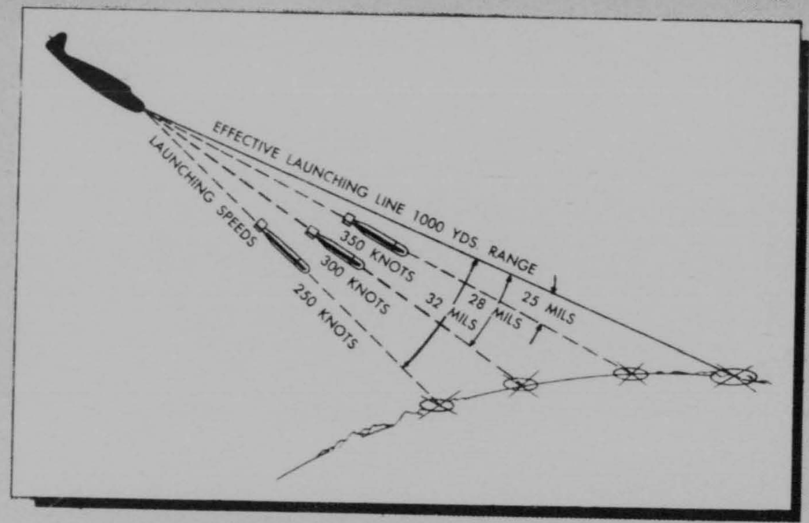

Figure 7–25. Effect of Launching Speed on Rocket Trajectory.

10. ROCKET TRAJECTORIES

Rocket Trajectories Versus Shell and Bomb Trajectories

Rocket trajectories lie between the trajectories of demolition bombs and the trajectory of shells. For example, for the same line of sight angle, the gravity drop of a shell is 7 mils, that of a rocket 28 mils and that of a demolition bomb 115 mils, a mil being the angle subtended by a chord 1 yard long at a distance of 1000 yards, or 1/6400 of the circumference of a circle. It will be noticed that the rocket trajectory is characterized by considerable curvature in contrast to the relatively straight trajectory of the shell. Since the rocket is slower than the shell, the longer time of flight for a given range tends to align it along the trajectory so that there is also a component of the jet force downward contributing to the drop from the launching line. Due to the consequent large curvature of the rocket trajectory, the sighting allowance required in aiming and its variation with dive angle are much greater for rockets than for shells. These differences, however, are less for shells than those for bombs. (Figure 7-23)

Effect of Dive Angle on Trajectory Drop of Rockets (For 0°, 20°, 40°, 60° and 80° Dives)

The trajectory drop decreases as the dive angle is increased, the drop varying roughly as the cosine of the dive angle. The sight setting is thus decreased as the dive angle is increased. However, the dive angle also affects the sight setting through its influence on the angle of attack of the aircraft. (Figure 7-24)

Effect of Launching Speed on Rocket Trajectory

The true (not indicated) air speed affects the gravity drop of a rocket. The greater the true air speed of the airplane at launching, the less will be gravity drop. This is a small effect compared to the effect of indicated air speed on altitude of the aircraft. (Figure 7-25)

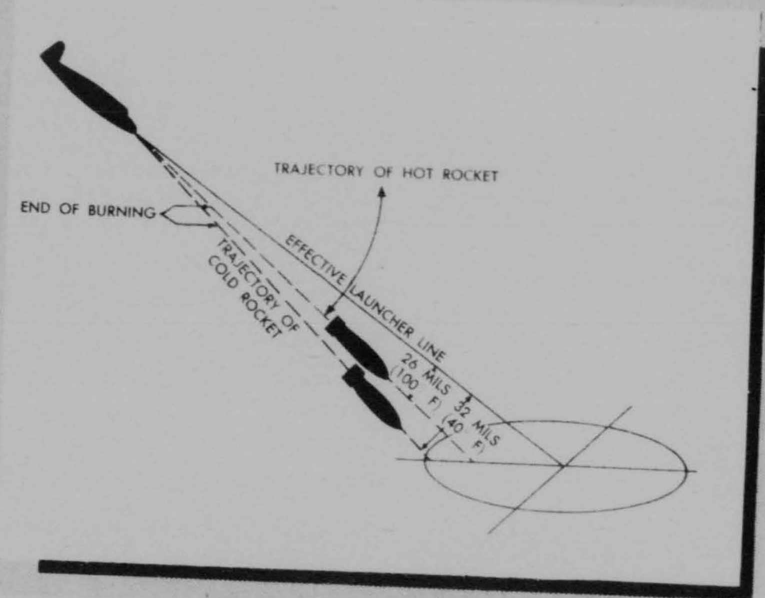

Figure 7–26. Effect of Temperature on Rocket Trajectory.

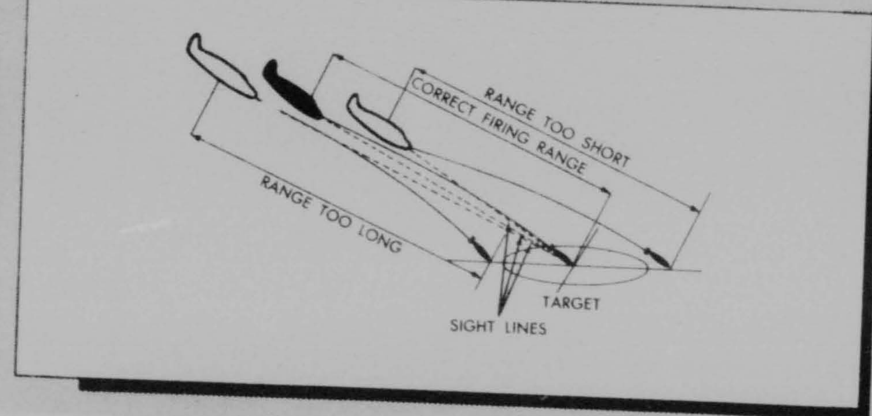

Figure 7–27. Effect of Range Misestimation.

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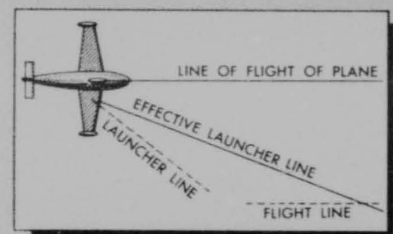

Figure 7—28. Effect of Flight Line on Rocket.

Effect of Temperature on Rocket Trajectory

The burning time and consequent burning distance of a rocket depend very greatly upon the temperature of the rocket propellant at ignition. Hence, since the trajectory drop is greater for increased burning time, it is obvious that the mil drop is greater for cold than for hot rounds. With some rockets, this may be a very important correction. For the 5.0" HVAR, the allowance is about 1 mil for each 10°F for firing at 1000 yard range in a dive at 300 knots. The variation is greater at the slower airplane speeds. (Figure 7-26)

Effect of Range Misestimation on Rocket Trajectories

It is important to judge range correctly because of the large curvature of the rocket trajectory. The errors due to range misestimation are apt to be the largest of those occurring in forward firing unless ranging equipment is available. For the 5.0" HVAR at 70° F fired in a 20° dive at 300 knots, the mil error for each 100 yards of range error is 1.6 mils. This figure increases for shallower dives and slower airplane speeds. (Figure 7-27)

Effect of Flight Line on Rocket, or Tendency of Rocket to Turn Into Flight Line Due to Malalignment of Launcher

Rockets tend to turn into flight line when launcher is canted from axis of airplane. The large fins which are employed in fin-stabilized rockets also make the rocket sensitive to the direction of the airstream past the aircraft.

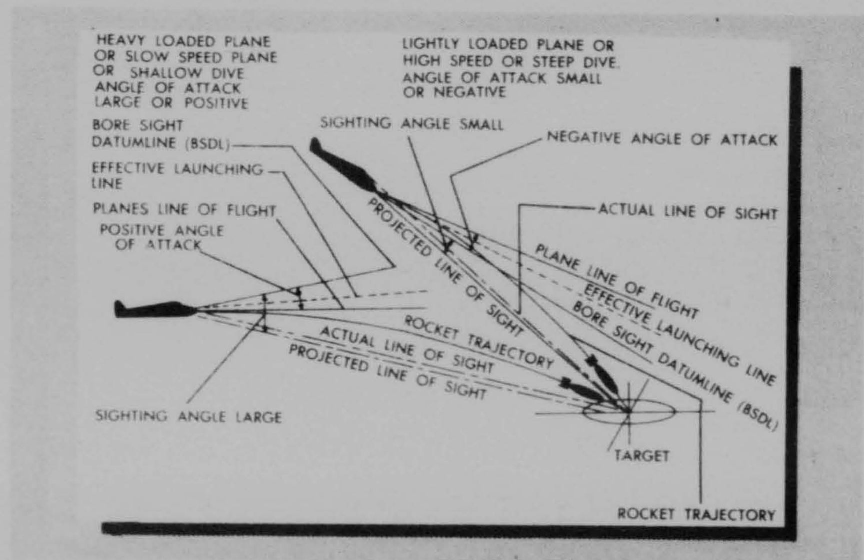

Figure 7—29. Effect of Angle of Attack on Aiming.

A rough rule is that fin-stabilized aircraft rockets launched from zero or post launchers follow the line of flight of the aircraft rather than the line of launch established by the post launchers. Launchers malaligned as much as 10 degrees causes the rocket to turn completely into the line of flight. Malalignment over 10 degrees causes approximately 90 per per cent complete turning into the line of flight. (Figure 7-28)

Effect of Plane Attitude or Angle of Attack on Aiming

Since the sighting angle is measured from a fixed line in the airplane (generally the boresight datum line BSDL), any change in orientation of this line will necessitate a change in the sighting allowance; hence an increase in the angle of attack BSDL (which means that the BSDL rides higher with respect to the flight line and the sight line to the target) will result in a large sighting angle. Conditions which tend to increase the angle of attack (and thus the sighting angle) are shallow dive, low indicated air speed, or heavy airplane loading. It is the indicated air speed, not the true air speed, which affects the angle of attack. The indicated air speed is dependent not only on true air speed, but on the pressure and temperature of the surrounding air or ambient temperature, which in turn varies with the altitude and climatic conditions. (Figure 7-29)

11. SIGHTING AND AIMING

As long as the aircraft follows a steady curve of approach in the attack, its line of flight will remain essentially unaltered even though bumpy air may cause rapid fluctuations in the relative position of pip and target. Therefore, a slight wandering of the aim around the target will not have an adverse effect on the accuracy provided the wandering is not consistently high or low or to one side. However, when the average aim point during approach is off the target, as illustrated in Figure 7-30, even though the pilot moves the pip on to the target at the instant of firing, the rocket will not strike the target, but will strike the average aim point instead.

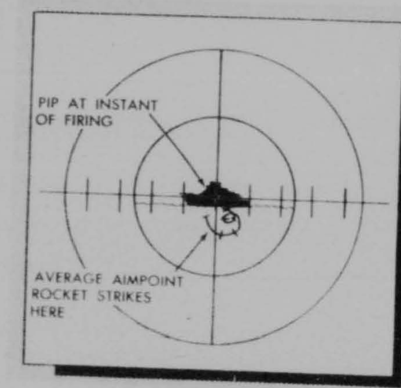

Figure 7—30. Effect of Wandering Sight Line.

The recommended approach, once the pilot is in the attack dive, is to get the pip on the target at least one second before reaching the firing range and keep it there until the instant of firing. Whether positive or negative attitude is induced on the aircraft in this curve of approach depends on whether or not the airplane is still accelerating, and on the range, air speed, sight setting, wind, and characteristics of the airplane. The motion of the target, if moving at rapid speed, must be taken into consideration, especially against aircraft targets, in which case proper lead must be taken depending on the speed of the rocket being fired. It is important, therefore, that complete information on sighting instructions be obtained both for the type or model of airplane as well as the type of rocket being fired. These may be found in Technical Orders pertaining to that aircraft and in rocket firing tables.

12. CLASSIFICATION OF AIRCRAFT ROCKETS

Aircraft rockets being similar to other ammunition, as far as the mission to be performed at the target is concerned, are classified similarly. The general classifications are as follows:

According to Service Use:

Service rockets are used for performing a mission at the target because they are fired against the enemy.

4.5 INCH ROCKETS

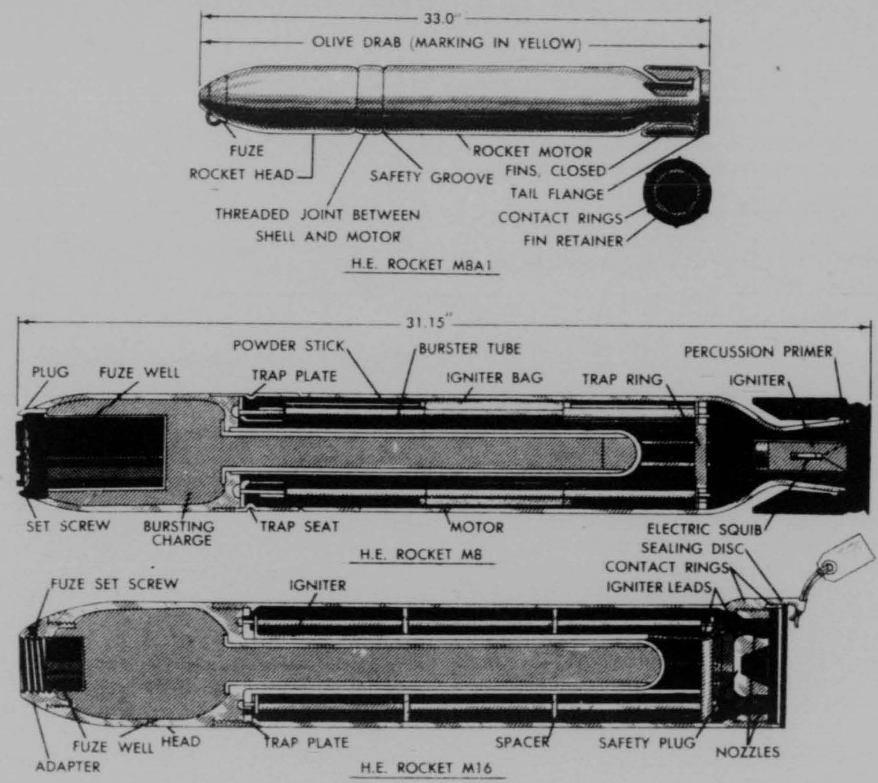

Figure 7—31. Sections of Unfuzed Rockets.

Practice rockets, and subcaliber rockets are used for marksmanship training and operation of launchers.

Drill rockets are used for training.

According to Tactical Use:

High-explosive rockets are those with high-explosive heads for demolition and fragmentation.

Armor-piercing rockets are those with heavy armor-piercing heads and smaller explosive percentage.

Semi-armor-piercing rockets similar to the SAP Bomb, are a compromise between HE and AP rockets.

Chemical rockets have heads loaded with chemicals.

According to Method of Stabilization:

Fin-stabilized rockets are equipped with either fixed fins, or folding fins.

Spin-stabilized rockets are equipped with several nozzles canted sideways from the axis of the rocket, so as to create a torque which makes it spin.

Target Rockets:

For training of antiaircraft artillery batteries or for rocket-interceptor training in defense against rockets.

13. ROCKET COMPONENTS

Head (Payload)

The function of the head is to destroy the target by blast, fragmentation, or otherwise. Rocket heads are classified as high explosive (HE), high-explosive antitank (heat), semi-armor-piercing (SAP), chemical, flare, photo-flash, instrument-loaded, parachute, and practice. The type of filler can be identified by markings on the head. The head may use either or both nose and base fuzes which are threaded into adapters. Booster cups are also contained in the head to insure detonation of the explosive charge. (Figure 7-31)

Motor

The purpose of the motor is to give the rocket its propulsion or motive power. Its principal parts are as follows:

Motor Tube. This is a seamless steel tube threaded at one end to receive the head. It encloses the combustion chamber in which the propellant is burned. It houses the solid or liquid fuel. If liquid fuel is used, the combustion chamber is sometimes surrounded with double concentric tanks which serve the double purpose of cooling the combustion chamber and preheating the fuel. The oxidizing agent, such as liquid oxygen, and the fuel, such as kerosene, each occupy one of the concentric tanks. This type of rocket is known as regenerative. At present there are no liquid-fuel aircraft rockets. The suspension bands provide either button-type lugs, or tunnel-type lugs for suspending the rocket attached to the motor tube. Usual distance between centers for aircraft rockets of lugs is either approximately 17½ inches or 35¼ inches. The walls of the motor tube are relatively thin, usually less than 0.25" because of comparatively low pressure. Near the head there is a safety ring groove which allows the tube to break at this point in event of excessive pressure in the combustion chamber.

Trap (Grid). The trap supports the powder grain before and while burning, and at the same time, allows enough clearance for the gases to escape. Traps vary in form and dimension. Perforated grains usually are strung on wire traps. Single grains are molded onto the trap frame.

Propellent Grain. Double-base nitroglycerine, nitrocellulose powder is either perforated to prevent degressive burning or is shaped to provide the desired burning characteristics. It may be provided with surface inert strips known as inhibitors to limit the amount of surface exposed to burning.

Pads, Washers, Spacers. Between the end of the propellent grain and head is usually a felt pad to cushion shock to the propellant. There is also an inlet filter washer and a hollow spacer to prevent the melted motor components and fragments of debris from clogging the pressure vent to the base fuze, which in many cases is pressure armed. A blowout disc is provided on this pressure vent. A metal shipping cap protects the threads on the motor.

Nozzle. The nozzle is a venturi-shaped orifice consisting of a convergent section, a throat of minimum diameter, and a divergent section which directs the flow of gases in the desired direction and provides for expansion of the gases in the exit cone to as close to atmospheric pressure as practical without having the exit cone too long. The venturi shape allows nonturbulent expansion of gases and provides an additional 33 per cent thrust over a simple convergent opening. In spin-stabilized rockets the nozzles are arranged symmetrically about a circumference but each with its axis canted from the rocket axis so as to provide a torque causing rapid rotation. Prior to firing, the nozzles are plugged with a sealing compound to protect the propellant from moisture. These seals are blown out when the rocket is fired.

Igniter. The igniter is a device for precisely igniting the propellent, thus initiating functioning of the rocket. An igniter such as the bayonet type consists of four parts: a squib, electrical connections, a charge of black powder, and the body or case, which is made of a special celluloid resistant to nitroglycerine which softens ordinary celluloid. Celluloid or other plastics are required to seal the hygroscopic black powder from moisture. The plastic seal for the black powder is better than

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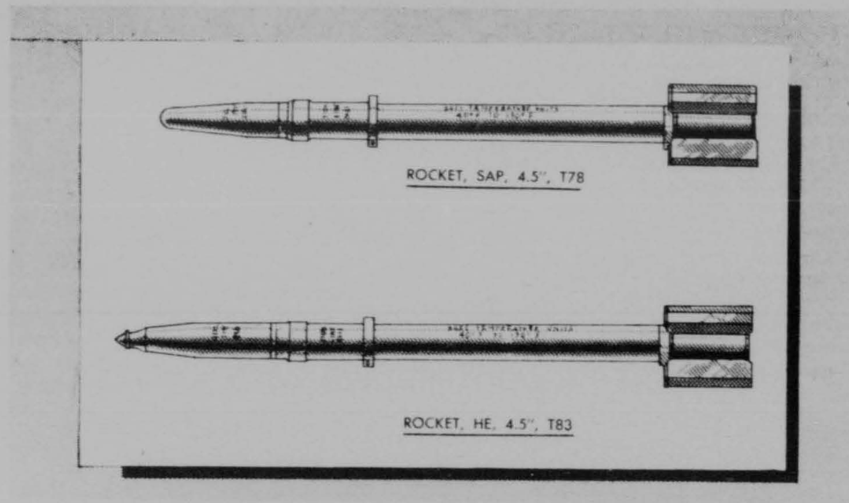

Figure 7—32. 4.5 Inch Fixed Fin Rockets.

having it loose in bags because shorter ignition times are obtained, thereby benefiting the accuracy by firing at the instant of aiming. The normal firing delay is between 10 and 30 mille-seconds. There are also fuze-type or suspended igniters which work by a flash of flame. Sometimes, the igniters are cupshaped, but work on the same principle of intensive flash of fire to ignite the propellant at the instant the firing trigger is depressed.

Fin Assembly. The function of the fins is to provide stability in flight, prevent tumbling and insure head-on impact. Fins may be of fixed or folding type. The action of the air on the fins restores balance and causes the rocket to move in a head-on direction. Fins on rockets are sometimes provided with gyro-controlled surfaces in which case the rocket becomes a guided missile. The tendency of these controls is to produce wandering of the rocket about a smooth line of trajectory. A bent fin will produce excessive yaw during burning so that the thrust is in the wrong direction. Fin-stabilized rockets usually rotate slowly due to slight differences in rocket symmetry. Spin-stabilized rockets rotate rapidly and have more tendency to yaw—which is the tendency of the nose to revolve about the line of trajectory, resembling a spiral-weaving action of the projectile. Spin-stabilized rockets, however, are more accurate than the fin-stabilized type.

14. AIRCRAFT ROCKET TYPES, MODELS, AND DATA

Principal Types

2.25" Sub-caliber Rocket, SCAR, Fin-stabilized Practice Rocket. This is supplied in two types to match the trajectories of the 5.0" HVAR and 5.0" AR respectively. This was formerly accomplished by providing a light and a heavy head. At present the weight and the head are kept constant and the motor varied. The 2.25" rocket head MK 1 and modifications, or MK33 and modifications, are issued with the 2.25" rocket motor MK 10 and modifications (fast motor) to match the trajectory of the HVAR; and with the 2.25" rocket motor MK 12 (slow motor) to simulate the 5.0" AR.

3.5" aircraft rocket, AR, fin-stabilized. The 3.5" rocket head has been manufactured in TNT, FS, WP and special loaded models. However, the only types currently issued through Army ordnance channels are the solid shot MK 2 and MK 8.

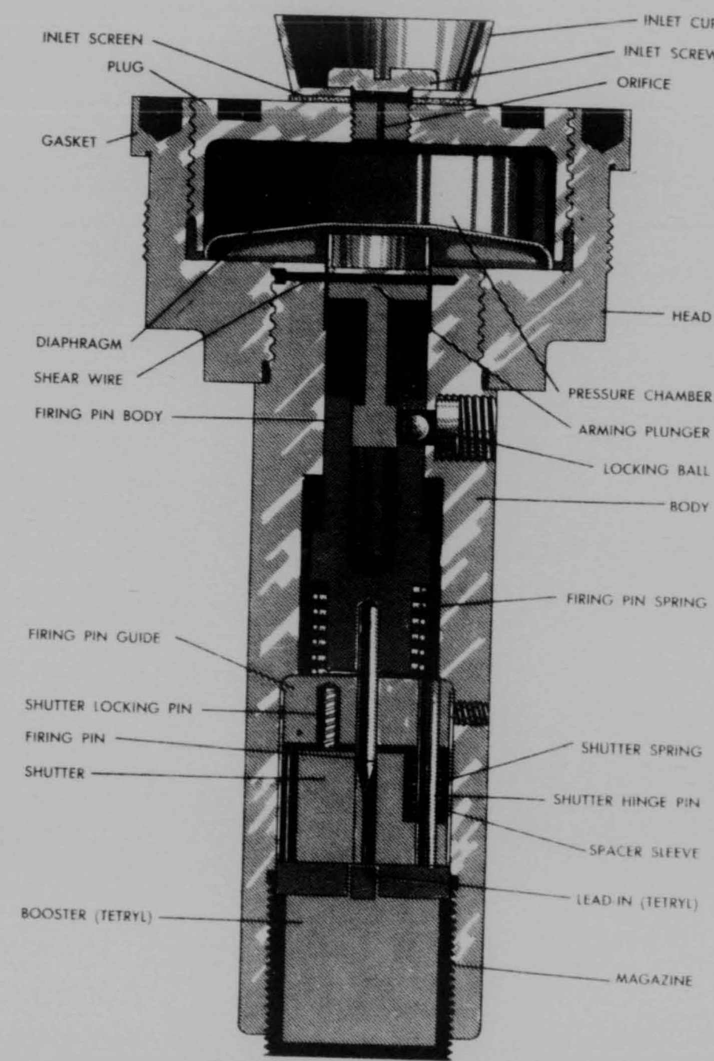

Figure 7—33. Base Fuze, MK 157 (PIR).

3.5″ aircraft rocket motor with 5.0″ head, fin-stabilized. This, as the name implies, is merely the 3.5″ rocket motor bushed to receive the standard 5.0″ AR rocket head. The various modifications of the 3.5″ rocket motor MK 7 are in details of nozzle construction.

5.0″ high-velocity aircraft rocket HVAR, fin-stabilized. The 5.0″ rocket heads MK 5 and modifications and MK 6 head and modifications essentially are the same except for details of the base-fuze assembly. The 5.0″ rocket motors differ principally in the fin assembly; MK 1 and MK 2 Mod. 0 had fins welded to the motor, MK 2 Mod. 2 had fins attached to a sleeve which is assembled to the motor as issued; and MK 2 Mod. 3 has fin issued separately.

5.0″ aircraft rocket, AR, fin-stabilized. The 5.0″ rocket head MK 1 on this rocket can be distinguished from the HVAR by the internally threaded motor adapter.

11.75″ AR (Tiny Tim)

This model uses a 500 S.A.P. bomb (AN-M58) filled with TNT and wells for 3, MK 163 base fuzes in the head. It has no nose fuze. The reason for using thre base fuzes is for positive detonation of the TNT filler. The MK-2 11.75″ H.E. head is used with the MK 1 Mod 3, 11.75″ rocket motor only. The MK-4, 11.75″ high explosive head (Tiny Tim) is used with the MK-2, 11.75″ rocket motor, only. The MK-2 and MK-4 heads are not interchangeable due to the size of the threads. The MK-4 head will have finer threads than the MK-2. The total weight of the 11.75″ Tiny Tim is 1280 lbs. and it is approximately 10 ft. long.

Painting

In general, rocket motors are painted olive drab. The colors used for rocket heads are as follows:

High-explosive. Painted lusterless olive drab; marked in yellow.

Chemical (gas). Painted lusterless grey; marked in green.

Chemical (smoke). Painted lusterless grey; marked in yellow.

Statistical and Identification Data on Aircraft Rockets

	5.0″ HVAR	5.0″ AR	3.5″ AR	2.25″ AR
Length	68.9 in.	65.8 in.	54.7 in.	29.2 in.
Weight	134 lb.	85.5 lb.	54.7 lb.	11.9 lb.
Range (Max. Eff.)	4000 yd.	2000 yd.	4000 yd.	2000 yd.
Velocity (Max.)	1350 FPS	760 FPS	1150 FPS	1170 FPS
Temp. Limits	0 to 120 deg. F.	0 to 120 deg. F.	0 to 120 deg. F.	0 to 120 deg. F.
Burning Time	0.9 to 1.4 sec.	0.61 to 1.5 sec.	0.61 to 1.5 sec.	0.38 to 0.91 sec.
Propellant Wgt.	24.8 lb.	8.5 lb.	8.5 lb.	1.75 lb.
Nose Fuze Model	MK 149	MK 149	MK 149	None
Nose Fuze Type	Air-Sq.	Air-Sq.	Air-Sq.	——
Base Fuze Model	MK-157	MK 157	None	None
Base Fuze Type	Pir.-0.020	Pir.-0.020	——	——
Alternate Base Fuze Model	MK-159	MK 159	None	None
Alt. Base Fuze Type	Pir 0.015 sec. delay	Pir. 0.015 sec. delay	None	None

Data (4.5 Inch Rockets)

	HET-83	SAP 78
Length	75.88 in.	70.89 in.
Weight	98 lbs.	98 lbs.
Range	1,500 yds.	1,500 yds.
Dispersion (lateral)	5 mils	5 mils
Velocity (max.) (relative to AC)	1,000 fps.	1,000 fps.
Temperature limits	—40 to 1130 F.	—40 to 1130 F.
Burning time	0.7 to 0.3 sec.	0.7 to 0.3 sec.
Burn Out time	700 to 300 ft.	700 to 300 ft.
Head, Length	16.68 inches	15 inches
Head, Wt. Filler	8.8 lbs	2.8 lbs.
Propellant	14 lb.	14 lb.
Fuze Model	MK 149	T 156
Fuze Type (action)	PD, SQ	BD, 0.017 sec. delay

Chemical (incendiary). Painted lusterless olive drab; marked in purple.

Practice. Painted lusterless blue; marked white.

Inert. Painted black; marked in white.

15. ROCKET FUZES

Rocket fuzes are components of the head, but are usually taken up separately because of their importance, intricate nature, and many types. The function of the fuze is to explode the burster charge in the head. Rocket fuzes

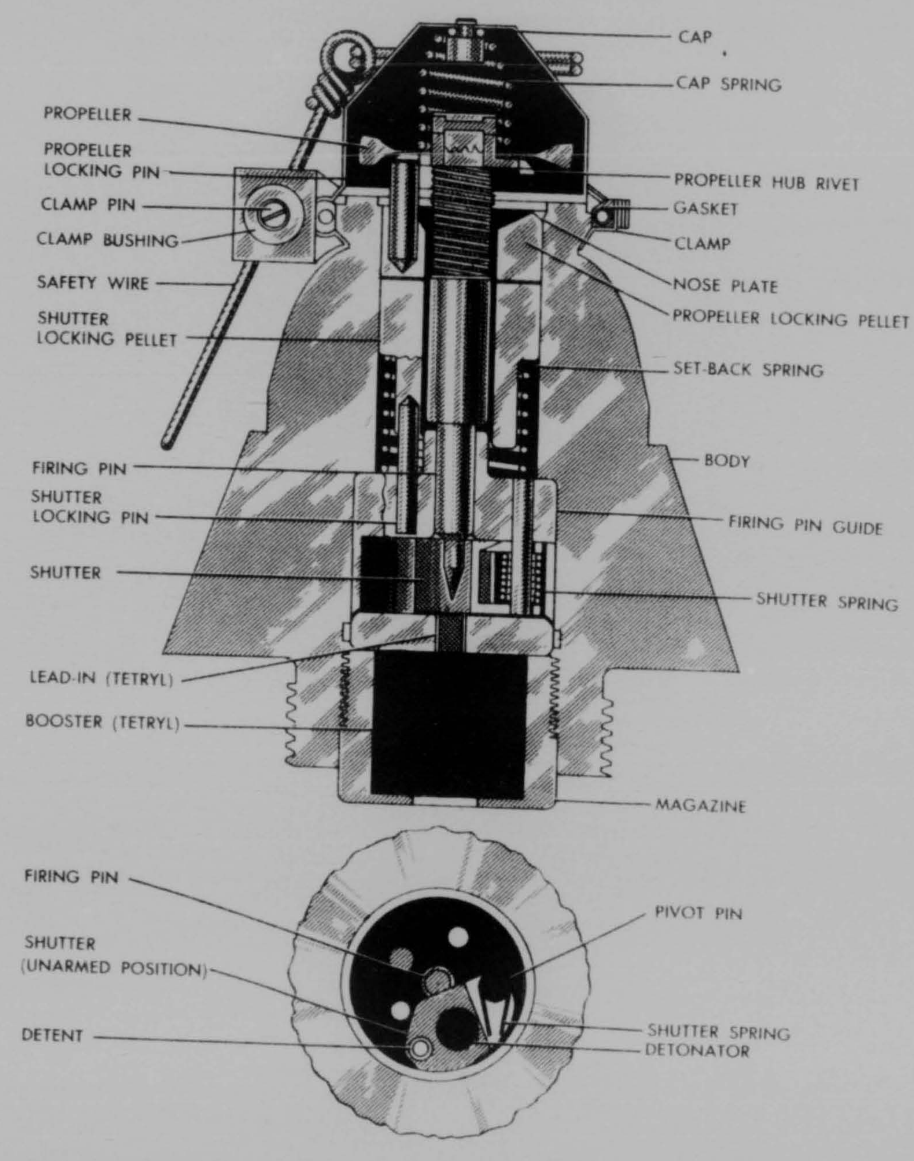

Figure 7—34. Air 8 Fuze.

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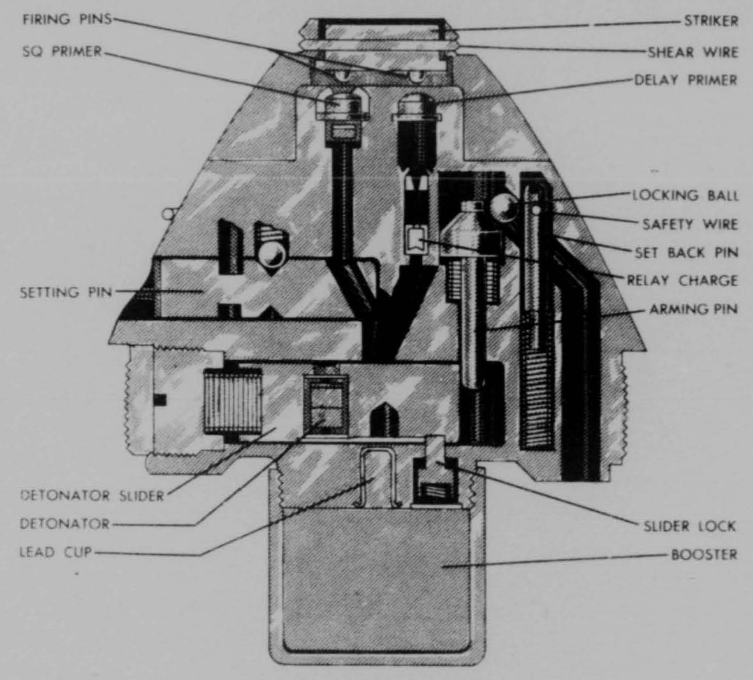

Figure 7–35. PD Fuze M4A2 Schematic Section.

at present are either nose or tail fuzes, though transverse or side fuzes could be used if the rotation of the rocket were taken into consideration. Except for minor differences, rocket fuzes are similar to bomb fuzes. Rocket fuzes are designed to arm where the set back is small and for this reason are generally more sensitive than bomb or artillery fuzes. Base fuzes use pressure developed by the burning gases for arming. The pressure acts through a piston causing it to move so the firing pin may line up with the primer after set back ceases.

Normally, since aircraft follow closely the trajectory of their rockets, rocket fuzes travel a great distance before they are armed, usually not being completely armed until set back ceases at the end of the burning period. This is very important when firing at close ranges, as in the case of air to air combat.

Base Fuzes

No further preparations are necessary than to ascertain that the base fuze is present and in tightly; inasmuch as no safety wire is used, **a rocket designed for a base fuze must not be fired without one**, for a premature explosion of the rocket head would then occur before the rocket even left its launcher. The principal types of base fuses are the MK 157 with 0.020 second delay and MK 159 with .015 second delay. They are known as "pir" fuzes or pressure arming, impact operated. Other than the difference in delay the fuzes are identical. (Figure 7-33)

The functioning mechanism of the MK 157 and MK 159 fuzes is contained in two pieces, the head and the body. The head contains a gas chamber formed by the plug, and the diaphragm gases from the rocket motor are permitted to flow slowly into the gas chamber

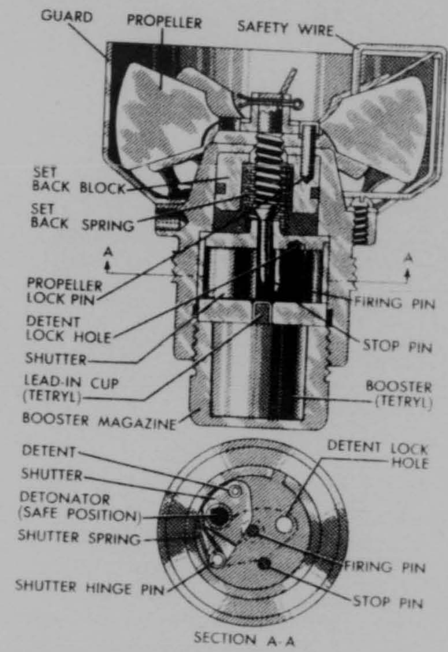

Figure 7–36. Nose Fuze MK 137 (AIR).

through an aperture in the inlet screw. When the pressure in the chamber reaches about 250 pounds per square inch, after about half the burning time of the propellant, the diaphragm collapses shearing a shear wire; this allows movement of a plunger and release of cockingball. After acceleration is over, the firing pin has been withdrawn from a shutter, the shutter has moved forward, and upon disengagement of the shutter cocking pin, it is swung into the armed position with the delay detonator in line with the firing pin.

Other base fuses are the M 146 (air), M 400 and M 401.

Nose Fuzes

The present most commonly used nose fuze is the MK 149. In the unarmed position, the firing pin is screwed down along side the detonator shutter holding it to one side. The propeller, or vane, attached to the firing pin is prevented from turning by the propeller locking pin attached to the propeller locking pellet. The cap on the nose of the fuze is held tightly in place on the gasket by a clamp assembly held together by a safety wire.

When the round is fired, the arming wire pulls free, releasing the clamp assembly which falls apart. The cap spring throws off the cap exposing the propeller. At the same time, acceleration retracts the propeller locking pellet releasing the propeller.

The fuze may be fired safe if the arming wire is released so that it stays with the fuze. In this case, the base fuze will operate giving a slight delay explosion.

Other nose fuzes are the M 4 A 2, MK 137, MK 149, and M 81.

Storage

Fuzes should be stored, separate from the other components, in dry indoor storage in a well-ventilated magazine, protected against the direct rays of the sun, excess moisture, and heat. They require especially careful handling to prevent shock. The individually, hermetically-sealed packing cans must not be opened prior to use.

16. INSPECTION OF ROCKETS AND GENERAL PREPARATIONS FOR FIRING ROCKETS

Components are removed from packings and inspected for serviceability. Rocket heads should be inspected to see that the fuze and adapter threads are undamaged, that the nose-fuze well contains an auxiliary booster and that heads adapted for base fuze have the base fuze assembled. Motors should be inspected to see that they are free from dents, threads clear, closing discs and short circuit clips are effectively in place, that fins are not bent and that lugs appropriate to the launcher are tightly secured in place. Fuzes should be inspected as specified for that particular fuze. Special instructions issued for particular fuze and rocket and temperature requirements should be checked.

The shipping plugs and caps are removed and the motor and head assembled. It is tightened with sharp wrenches. If necessary, fin is assembled to motor.

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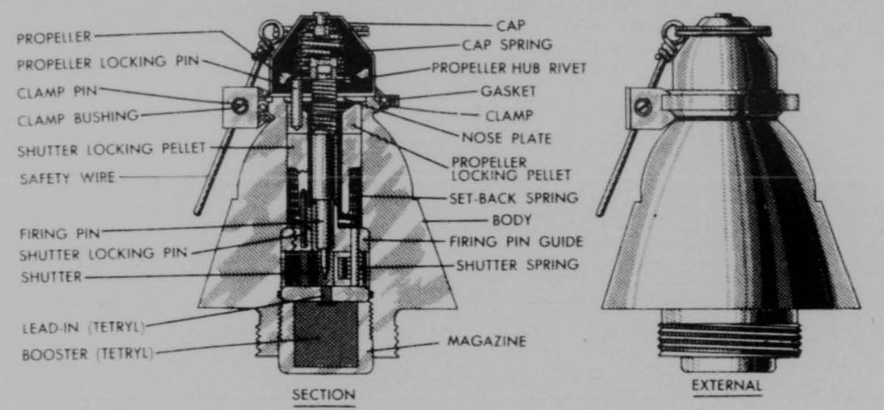

Figure 7—37. Nose Rocket Fuze MK 149.

The fuze is assembled to head as prescribed by special directions for the particular fuze.

All electrical connections and launching equipment are checked. They are tested with circuit testers.

The shorting clip is removed from fuse after rocket is loaded on launcher.

All safety regulations must be obeyed.

17. PRECAUTIONS

Unnecessary personnel must be kept away.

A safety man familiar with all safety regulations should be on hand to observe preparation for firing. Personnel must obey any safety orders issued.

Personnel working on rockets should stand on side of rocket—never in front or rear of rocket.

Rockets having base fuze must have base fuze assembled properly. If rocket is fired with base fuze missing rocket will detonate on launcher when fired.

All necessary electric circuit tests must be made prior to reloading rockets on launchers.

18. MAINTENANCE OF ROCKETS

Rockets and components must be regularly inspected and maintained in serviceable condition at all times. Proper paint should be applied, rust-preventative grease authorized for use should be used. Motors should never be stored with heads. Proper records should be maintained on incoming and outgoing shipments. Stock records must reflect accurately at all times particulars on rockets on hand, including lot numbers and place of storage. Special maintenance instructions for each component should be followed and proper records kept. Personnel must have thorough knowledge as to what is permissible in maintenance. Prompt and proper action must be taken in case reconditioning, renovation, or destruction is required. All safety regulations applying to maintenance and storage must be strictly followed such as adequacy of fire extinguishers, nonsparking tools used, safety shoes worn, and compliance with all other regulations required.

SECTION V—GLOSSARY OF TERMS

Acceleration. Rate of increase in velocity, measured in G's.

Airfoil. A thin streamlined surface used for wings, rudders, or flaps.

Air Resistance. The resistance produced by the atmosphere toward any object moving rapidly through it.

Air Sounding. Measurements of air conditions at high altitudes by a radio sound or similar equipment.

Air Stream Engine. A reaction motor that depends on the atmosphere to support combustion or increase the mass of the jet.

Ambient Temperature. Surrounding air temperature.

Ammunition. Munitions and their necessary components which contain an explosive or chemical filler designed for use in combat.

Angle of Attack. Attitude that aircraft assumes in flight.

A.R. Aircraft Rocket.

Area Ratio. The ratio between the mouth area and throat area of a rocket nozzle.

Armor-piercing. Projectiles with a hardened steel element designed to pierce armor plate in vehicles or planes.

Athodyd. Continuous duct engine.

Atmosphere. Air from sea level to 18000 feet.

Augmentor. Device used for increasing pressure, velocity of thrust.

Axial Flow Compressor. A rotary air compressor using propeller-like blades through which the air flows parallel to the shaft.

Axis of Thrust. An imaginary line drawn through the center of the jet of a rocket motor, along which the thrust or reaction of the motor is directed.

Basic Color Scheme. Term used in reference to identifying types of ammunition by colors. For example, high explosive ammunition is painted olive drab.

Black Powder. A low explosive made of sulphur, charcoal, and saltpeter. Used widely as a propellent charge.

Blast Chamber. The chamber in which a propellant is burned in a rocket motor of jet engine.

Body. As used in terms of military ammunition, the body is generally the case of any ammunition that contains the explosive or chemical filler, also the part to the rear of the bourrelet.

Booster Rocket. An auxiliary rocket device with a large thrust and brief firing time used to bring rocket or aircraft up to flying speed.

Bore Sighting. Procedure of aligning axis of bore with sights.

BSDL. Bore sighting datum line.

Burster. An explosive element found in chemical ammunition which bursts the shell enabling the chemicals to be dispersed.

Bursting Charge. This is the explosive filler in a bomb or shell. TNT or amatol are bursting charges.

Cable. Connection of rocket between ignitor and plug.

Catapult. A device for launching a rocket or airplane with high initial speed.

Cavity. As used in ammunition a cavity is any place in a bomb, projectile, or mine that is used to receive a fuse or tractor composition.

Center of Gravity. The point at which all the mass of any flying body appears to be concentrated.

Centrifugal Compressor. A rotary air compressor similar to a centrifugal pump in which air is thrown radially outward by vanes.

Ceramic Liner. A porcelain heat resistant lining for a combustion chamber.

Chuffing. Extinguishing and spontaneous reigniting of a grain of powder.

Chamber Pressure. Pressure shown by a gauge connected to the combustion chamber during firing.

Chemical Fuel Motor. A true rocket motor using propellants supplying their own oxygen (as opposed to air stream engines or ram jets which obtain their oxygen from the air).

Chugging. Irregular combustion due to incorrect mixture or poor chamber design.

Chute Boot. The parachute container of a sounding rocket.

Clinometer. Instrument used for measuring vertical angles accurately.

Closing Plug. A part of many types of ammunition that is added after the body has been filled with a high explosive. It is also used to protect fuze cavities until the time the fuze is actually inserted for use.

Combustion Chamber. An alternate name for blast chamber.

Compressibility Burble. An unsteady type of airflow around an air foil operating close to the speed of sound marked by reduced useful life and increased drag.

Concentric Tanks. Fuel or propellant tanks nested one within the other with a common central axis.

Construction Weight. The weight of tanks, motor, pumps, controls, landing gear, et cetera, of a rocket exclusive of fuel; an alternate name for structural weight.

Controlled Rocket. A rocket which has a guided mechanism capable of controlling the direction of flight.

Coolant. Any material used to cool a rocket combustion chamber or nozzle.

Cordite. A double base powder.

CV Aircraft. Carrier-borne aircraft of certain types.

DBT. Dibutylpthalate, an oily viscous liquid inert as an explosive.

Delayer. A substance mixed with the propellant of a dry-fuel rocket to decrease the rate of combustion.

Delay Train. A means provided in ammunition to delay the detonation. Black powder is commonly used.

Demolition. Destruction caused by blast of HE ammunition.

Depressor. Substance used to depress flash of propellants.

Detonation. The rapid explosion of a high explosive, or an explosive train.

Detonator. A highly-sensitive explosive used in an explosive train. It is usually initiated by a firing pin or striker. Azide is often used for this.

Dipropellant. A combination of two substances used as a rocket fuel.

Displacement. Swings rocket from carried position into firing position.

Dissociation. Decomposition of the burned gases in a combustion chamber at high temperature producing a loss of heat energy.

DNT. Dinitrotoluene which is a neutral solid used primarily as a stabilizer because it reduces hygroscopicity.

D.P.A. Diphenylamine, a stabilizer which acts by combining with nitrous fumes or exides of nitrogen evolved in deterioration of nitrocellulose.

Drag Coefficient. A factor representing the relative air resistance of a particular shape of airfoil.

Drop Unit. A booster rocket which can be jettisoned after exhaustion of its propellants.

Dud. Any explosive or chemical ammunition that had failed to function under normal conditions.

Dynameter. Device by means of which force is applied, or by which kinetic energy is converted into propulsion.

Dynamometer. A device for indicating and recording the thrust of a rocket motor during a test, also called a reaction balance.

Escape Velocity. The velocity at which an object would escape the gravitational attraction of a given astromical body. The escape velocity of the earth is 6.664 miles per second.

Explosive Train. The arrangement of explosives for a small charge of sensitive explosive to a large charge of comparatively insensitive explosive. Detonator booster, then bursting charge, in an arrangement of an explosive train.

Explosion. The sudden generation of a large volume of highly heated gases with the resultant pressures, and the fragmentation.

Explosive. Any mixture, or substance that upon application of heat or shock, suddenly undergoes a chemical change (from a solid to a gas), that produces a great quantity of heat and a large volume of gases.

Explosive Filler. The bursting charge of any type of ammunition.

External (or Ballistic Efficiency). The ratio between the energy usefully employed in propulsion and the kinetic energy developed by the jet; same as mechanical efficiency.

Filler. Contents carried in an ammunition container. They may be explosive, chemical, or inert.

Fill Hole. The orifice through which liquid fuels are loaded into a rocket tank.

Final Mass. The mass of the rocket at the end of flight.

Fins. A component part of some ammunition added to give stability in flight, preventing rotation. Bombs, rockets, and mortars have fins.

Fins. Fixed rudders on a rocket to help give it direction.

Fin-stabilized Rocket. A rocket which does not rotate in flight but is stabilized by means of fixed fins or vanes.

Flaps. Movable rudders, either attached to the fins or placed in the jet of a rocket, to direct the flight.

Flare. The bell-shaped inner curve of some types of rocket motor nozzles.

Flare Angle. See Taper.

Flow Meter. A device for measuring the rate of flow of liquids or gases.

FPS. Feet per second.

Fragmentation. The actual shattering of an item of ammunition by the bursting charge. It is the final result of the explosive train.

Fragments. Pieces of metal that are shattered at high velocity as a result of the bursting of the body or casing of ammunition.

Free Flight. The portion of a rocket's flight which follows the combustion of the fuel or the turning off of the rocket motor.

Free-flight Angle. The angular direction of a rocket with respect to the earth at the beginning of free flight.

Free Rocket. A rocket which has no guiding or flight-control devices other than fixed tail or fin surfaces.

Fuel. The combustible component of a rocket propellant. It often includes the oxidizer as well.

Fuel-weight Ratio. The ratio of the weight of a rocket's fuel to that of the empty rocket without fuel; also called fuel-structure ratio. It is equal to the mass ratio minus one.

Fuze. A mechanical device used to initiate the explosive train at the time desired and under proper circumstances. There is no definite type of fuze for all ammunition.

Fuze. Either nose fuze or base fuze of rocket. Function is to allow safety prior to arming and finally to detonate rocket on impact or time.

Fuze Cavity. Any opening provided at time of manufacture for the purpose of receiving a fuze. The fuze may or may not be assembled with the ammunition it is designed for.

G. Symbol for gravity, the unit of acceleration equal to 32.2 ft. per second.

Gantry. An inverted U-shaped frame with hoisting equipment and platform for working on rocket head and instruments prior to vertical launching.

Gapa. Ground-to-air pilotless aircraft; a rocket interceptor.

Gogetter. A control mechanism for large military rockets or robot planes especially one intended automatically to guide the rocket to target.

Grain. Shaped particle of powder propellant.

Grain. 1/7000 part of pound.

Grid. Trap, supports powder grain before and after burning.

Gyro Control. A gyroscopically-operated device for guiding a rocket in flight.

Harmonization. Procedure of aligning target of projectile with a sight at specific range.

HE. High Explosive.

Head. That part of rocket containing payload.

High Explosive. An explosive functioning with high-order detonation.

High-order Detonation. A complete and instantaneous detonation.

Hull. The outer casing of a large projectile.

HVAR. High-velocity aircraft rocket.

Ideal Rocket. A rocket constructed to such a fuel-weight ratio that it will reach the velocity of its own jet in space. This ratio would be 1 to 1.72, the larger number of referring to the fuel.

Igniter. A device such as a fuze for igniting a rocket motor.

Ignition Train. A series of low explosives provided for the specific purpose of propelling a projectile into flight. The train usually consists of the primer and propellant. The rapid expansion of the gases created from the burning of the propellant cause the flight of the projectile.

Impact. A term used in reference to ammunition designating the actual instant a projectile hits its target. Impact fuze is one that is detonated by impact alone and has no time-delay element.

Impulse. The total output of a jet motor in a given shot; equivalent to average reaction multiplied by time.

Impulse-weight Ratio. The ratio between impulse (reaction multiplied by total firing time) of a jet motor and the total loaded weight, including auxiliaries.

Incidence. Angle of mounting of wing, usually at about 3 degrees over horizontal.

Inhibitor. A strip of fire-resistant plastic that is bonded to the external surface to reduce degressive burning substances such as DNT which reduces hygroscopicity.

Initial Mass. The mass of the rocket at beginning of flight.

Injector. The inlet device which admits propellants to a rocket motor.

Inlet Ports. The openings or nozzles through which propellants are injected into the rocket motor.

Ionosphere. Altitudes above 87000 feet or above stratosphere extending to 200 miles above earth, 96 per cent of air is below ionosphere.

Japee. A jet engine or an aircraft driven by jet propulsion.

Jato. Apparatus for producing jet-assisted take-off or an aeroplane so equipped.

Jet. The stream of gas effected by a reaction motor.

Jet-assisted Take-off. An airplane take-off accelerated by the use of a thrust or rocket or jato.

Jet Engine. An airstream engine; a reaction motor equipped to use oxygen of the air as an oxidizer; types, ram jet, turbo jet, impulse jet, thermojet, and continuous duct engine known as athodyd.

Jet Motor. A self-contained or true rocket motor; a reaction motor supplied with oxygen as one of its propellants, as contrasted with the jet engine or airstream engine or ram jet engine.

Jet Propulsion. Rocket power: propulsion by thrust developed by ejecting a jet of rapidly moving gas or other substance through a nozzle.

Landing Gear. Equipment usually consisting of a parachute and release mechanism for bringing a rocket gradually to earth after a shot.

Launching Angle. The angle measured from a horizontal plane, at which a rocket is inclined at launching.

Launching Rack. A fixed rocket launcher.

Launching Rails. Rail type launching device.

Launching Trough. Trough type launching device usually semicircular in section.

Lead Azide. An extremely sensitive high explosive used in primers or detonators along with other explosives to initiate an explosive train. It is very sensitive to fire, but not impact alone.

L/D Ratio. The ratio of length to diameter of a rocket-motor combustion chamber.

Liquid-fuel Propellant. Liquid mixture usually hydrocarbons such as kerosene, alcohol, gasoline, liquid hydrogen.

LOS. Line of Sight.

Low Explosive. A relatively slow-burning explosive which does not ordinarily detonate, for example FNH powder.

Lox or Loxygen. Liquid oxygen.

Lug Bands. Bands equipped with appropriate fittings which are attached to the motor tube, and used to suspend the rocket from rail or post type of launchers. Two types of lugs are button type, and tunnel type.

Mach Number. The ratio of the velocity of a rocket or jet to that of sound in the medium being considered.

Mach Waves. Nodes or standing waves in a rocket jet caused by reflection of the jet from the surrounding air.

Mass Ratio. The ratio between the total mass of the rocket ready to shoot and the final mass of the empty rocket.

Mechanical Efficiency. The ratio between the energy usefully employed in propulsion and the kinetic energy developed by the jet (same as ballistics or external efficiency).

Mechanical Time Fuze. Any fuze whose action is controlled by clocklike mechanism. Such fuzes may be found on bombs or artillery shells. Usually they will provide for several seconds delay in the operation of the fuze.

Mercury Fulminate. Another extremely sensitive high explosive used in detonators. It is very sensitive to fire, or impact from a firing pin.

Meteorgraph. An apparatus for determining or recording atmospheric data.

Metering Orifice. An apparatus for determining or recording atmospheric data.

Mono Propellant. A propellant consisting of a single liquid which contains both fuel and oxidizer either combined chemically or a mixture.

Motor. The device that provides thrust for a rocket; alternatives; jet motor, rocket motor, thrust motor, reaction motor; includes propellent charge and support, cable and plug, motor tube and nozzles.

Motor Head. The upper portion of a rocket motor, usually containing the propellent injection parts and the igniter.

Motor Tube. Seamless threaded at one end to receive the head.

Mouth. The large end of the expansion nozzle.

Mouth Area. The cross-section of the nozzle mouth.

Multi-nozzle Motor. A rocket motor with more than one nozzle.

NACA. National Advisory Committee for Aeronautics, Washington, D. C. in charge of research data for use in the design and operations of missiles to be developed, by the Army, Navy, and Air Force.

NDRC. National Defense Research Committee.

Nondelay Fuze. A fuze designed to burst a projectile outside its target before penetration or ricochet.

Nozzle. The orifice and expansion device through which the jet is ejected from a rocket motor.

Nozzle Coefficient. The amount experimentally determined by which the shape of a specific nozzle increases the thrust of the motor.

Opacifier. Substance used to absorb the radiation produced by the burning surfaces. Should the powder grain absorb these radiations, the absorbing area becomes heated and decomposition or breakage of the grain is liable to result.

Oxidizer. The oxidizing component of a rocket propellant such as liquid oxygen, hydrogen peroxide, potassium chlorate.

Parachute Release. An automatic device for ejecting a landing parachute from a rocket.

Parallel Tank Rocket. A rocket with parallel, cylindrical fuel tanks.

Payload. The useful load carried by the rocket in addition to its necessary structural weight and fuel.

Pentolite. A high explosive of an insensitive nature used as a filler. It is a mixture of TNT and PETN. Many rockets have a pentolite filler.

Photoflash Bomb. One type of pyrotechnic dropped from aircraft, which produces a brilliant flash of light sufficient for photographic purposes.

Plasticizer. A material used in a powder to hold the ingredients in close bond.

Plug. Connector of cable to aircraft electrical circuit.

Post. Rocket carried under post or posts by means of fittings on the rocket motor tube.

Powdered Flight. The portion of a rocket's flight during which the rocket motor is in operation.

Primer. A device used to ignite a propelling charge. It is fired by shock from a firing pin or striker.

Projected Area. The maximum cross section of a rocket hull when viewed head-on.

Propellant.-A propelling agent; the low explosive which upon ignition propels a projectile from the weapon.

Propellants, Composite. Powders of at least 2 components such as equal amounts of ammonium picrate and sodium nitrate with an added plasticizer.

Propellants, Liquid. Types kerosene, gasoline, alcohol and other hydrocarbons.

Propellants, Solid. Ballistite, smokeless powder, cordite, gun powder.

Propellent. (adjective) Able to propel.

Propelling Charge. A definite quantity of low explosive used to propel a projectile. The charge is ignited by the primer turning to a gas.

Proving Stand. An equipment for testing or proving rocket motors also known as test stands.

PSF Ratio. The payload-structural-fuel ratio.

Pulse Jet. An intermittent jet.

Pyrotechnic Fuel. A solid propellant which supplies its own oxidizer as part of the mixture as in the case of gun-powder.

Radio Sonde. A form of meteorgraph transmitting its indications automatically by radio; used in high altitude air soundings.

Rato. Rocket-assisted take-off, an early use was on B-25 planes.

Reaction. The recoil or "kick" produced by the jet of a reaction motor which provides the propulsion force.

Reaction Motor. The general term for all types of jet-propulsion motors and engines.

Reflector Plate. Transparent mirror of optical sight on which reticle image is projected.

Regenerative Motor. A rocket motor equipped with a cooling jacket through which the fuel flows on its way to the injector, thus carrying the waste heat back into the blast chamber.

Regulator. A device for regulating the flow or pressure of a gas.

Relative Wind. Direction of wind with respect to direction of flight of the rockets.

Resonator. An impulse jet of intermittent type.

Reticle. That part of a sight which has a ring or bead cut out of thin metal plate or etched on the back of a mirror in an optical sight.

RPLCS. Rocket-propelled landing-craft support; applied to rocket-propelled boats used to lay smoke screen prior to amphibious landings.

Rocket. A projectile driven by jet propulsion.

Rocket Field. A proving field or area for rocket experimenting.

Rocketor. A rocket engineer or rocket experimenter.

Rocketry. The field of rocket theory, development, research, and experimentation.

Rudder. A steering device either attached to fixed fins or placed in the jet of a rocket to direct the flight.

Rupture Disc. A thin disc of special metal used as a safety valve.

Safety Groove. A groove on the motor of a rocket near the head to weaken it so that

it would break at this point in case of excess pressure.

Safety Valve. A valve placed in an oxygen or pressure tank to relieve the pressure before it reaches the bursting point of the tank.

Scar. Subcaliber aircraft rocket.

Sectional Density. The weight of a rocket divided by its maximum cross-section used in estimating air resistance.

Shear Wire. Wire used for safety purposes which shears on functioning of rocket.

Shock Waves. Sound waves set up by an object moving at supersonic speeds, causing increased energy losses.

Shot. A rocket flight.

Shroud. A curved stabilizing or control surface at the tail of the rocket.

Skin Friction. The drag of an object moving in air caused by the air on the surface.

Slant Range. Airline distance from airplane to target; useful in dive rocketry and dive bombing.

Socket. Receives the plug of the rocket.

Solid-Fuel Rocket. A rocket propelled by a solid or dry pyrotechnic propellant.

Solid Motor. A nonregenerative liquid fuel rocket motor.

Solventless Process. Relatively dry process of manufacture of propellants.

Solvent Process. Liquid process of manufacture of propellants usually with ingredients containing nitroglycerine, alcohol, and acetone.

Sounding Rocket. A high-altitude rocket carrying air-sounding equipment.

Spacer. A device for separating sections of a rocket or to act as an insulator.

Spinner. A winged device like the rotor of an auto gyro, used instead of a parachute to bring a rocket gently to earth.

Spin-Stabilized Rocket. A rocket designed to rotate rapidly during flight thus obtaining stability in the same manner as an artillery shell.

Stabilizer. Fin member to produce stability of flight.

Stabilizer (chemical). Substance added to powder to aid in preventing decomposition usually by absorbing gaseous products of slow decomposition.

Step Rocket. A rocket consisting of several sections or "steps" fired successfully each step being jettisoned when its fuel is exhausted.

Stratosphere. Altitude from 35,000 feet to 87,000 feet.

Super-Sensitive Fuze. A fuze which is designed to function upon impact with a very light target.

Tandem Tank Rocket. A rocket with cylindrical propellant and pressure tanks placed end to end; a single-stick rocket.

Taper. The angle.

Test Stand. Same as proving stand.

Thermal Efficiency. The ratio of the kinetic energy developed by the rocket jet to the thermal energy content of the fuel.

Thermal Jet Engine. A type of airstream engine containing a rotary air compressor to provide air under pressure to sustain combustion.

Third Law of Motion. Sir Isaac Newton's statement of the principle upon which the reaction motor works "To every action there is always an equal and contrary reaction; the mutual actions of any two bodies are always equal and oppositely directed."

Throat. The narrowest part of a rocket nozzle.

Throat Area. Cross-sectional area of the narrowest part of the nozzle.

Thrust. The push produced by a jet or rocket motor.

Thrust Augmentor. A funnel-like device for guiding the surrounding air into a rocket jet thus producing suction which increases the thrust.

Tracker. A mechanism for observing or controlling a flying rocket from the ground, or the man operating such a device.

Trajectory. The curve which a body as a missile describes, influenced by the force of gravity.

Trap Plate. Grid or support for powder grain during burning.

Tropopause. Thin layer of upper air between troposphere and stratosphere.

Troposphere. Upper air from 18,000 feet to 35,000 feet.

True Rocket Motor. A self-contained, or chemical-fuel motor.

Turbo Jet. A thermal jet engine in which the compressor is driven by a gasturbine.

Valve Man. The operator who actually fires a liquid fuel rocket.

Velocity, Hypersonic. Velocities above 5,000 miles per hour.

Velocity, Subsonic. A velocity less than that of sound.

Velocity, Supersonic. A velocity greater than sound.

Velocity of Sound at Sea-Level. 1,100 feet per second or 750 miles per hour; lower at higher levels.

Venturi. The nozzle shape which consists of a cone-shaped restriction to the throat or narrowest section, and then expands in a cone shape to the exit.

VJ. The jet velocity of reaction motor.

War Head. The explosive section of a military rocket.

Weight-Fuel Ratio. The ratio between the structural weight and the fuel weight.

Weight Ratio. Same as mass ratio.

Wetted Surface. The total external surface of a streamlined hull exposed to air friction.

White Cellulose. Gun cotton.

Windage. Allowance for effect of wind on trajectory.

Zero Launcher. Launcher which releases rocket within movement of one inch or less.

CHAPTER 8—STORAGE, HANDLING, AND INSPECTION

SECTION I—STORAGE OF AMMUNITION AND EXPLOSIVES

1. GENERAL

In order that ammunition and explosives be safely and adequately stored, they must be stored in conformance with accepted principles of ammunition storage. These principles involve:

- Mixed storage regulations
- Quantity distance regulations
- Fire hazards
- Stacking and piling

2. MIXED STORAGE REGULATIONS

Purpose

Under normal storage conditions (when ammunition is stored within a standard ammunition magazine), the mixed storage regulations govern what items of ammunition or explosives may be stored together within a single magazine. Under field conditions (when ammunition is stored out of cover), the mixed storage regulations indicate what items of ammunition or explosives may be stored together within a single field storage unit.

Theory

Prior to World War I, mixed storage regulations were nonexistent because the few items of military ammunition and explosives that were used at that time had relatively the same characteristics and thereby presented no mixed storage problem. World War I in-

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GROUPS	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII
I. Cartridges for small arms and other similar cartridges	X	X	O	O	O	O	O	X	X	X	X	X	O	O	O	O	O	O
II. Military pyrotechnics	X	X																
III. Smoke ammunition, except WP	O		X	X	O	O												
IV. Incendiary bombs, grenades and rockets	O		X	X	O	O												
V. WP ammunition	O		O	O	X	O												
VI. Chemical ammunition	O		O	O	O	X												
VII. Separate-loading propelling charges and bulk powder.	O						X											
VIII. Fuzes, primers, bursters, boosters, etc.	X							X										
IX. Fixed and semifixed ammunition except gas and smoke	X								X	X	O	O						
X. Mortar ammunition and grenades except gas and smoke	X								X	X	O	O						
XI. Rockets, except gas and smoke	X								O	O	X	O						
XII. Land mines, mortar ammunition and fragmentation bombs	X								O	O	O	X						
XIII. Separate-loading projectiles	O												X					
XIV. Bombs, depth charges, aerial mines except gas and smoke	O													X				
XV. Demolition materials	O														X	O	O	O
XVI. Dynamite	O														O	X	O	O
XVII. Black powder ammunition and bulk black powder	O														O	O	X	O
XVIII. Photoflash bombs	O														O	O	O	X

[1]An "X" at the intersection of a horizontal row and a vertical column denotes that all items in the two groups may be stored together.
[2]An "O" at the intersection of a horizontal row and a vertical column denotes that all items in the two groups may be stored together if the explosive content of the items of the two groups stored together in one magazine or revetment does not exceed 1000 pounds.

Figure 8–1. Combination Storage Chart.

troduced, among other new types of ammunitions, chemical ammunition. When, after World War I, large stock piles of military ammunition and explosives were accumulated into stock piles, serious fires and explosions taught the lesson that many of these new items of munitions were not compatible with each other and had to be segregated for storage purposes.

Result of an Explosion

If the explosion of one type of ammunition is likely to cause the explosion of another type, the two types should never be stored together. An example involves dynamite and fragmentation bombs. An explosion involving fragmentation bombs would set loose large quantities of high velocity missiles while a dynamite explosion would result in shock or concussion. Were they to be stored together, the dynamite would be exposed to missile hazard; should the bombs detonate, the missiles being propelled by them would in turn detonate the dynamite. Were the situation reversed and the dynamite initiated, the shock or concussion from the dynamite would through sympathetic detonation, set off the bombs. Were this not the case, the bombs themselves could be propelled and become missiles in themselves.

Ease of Deterioration

An item of ammunition which does not tend to deteriorate readily should never be stored with one that does, for example, bulk smokeless powder and TNT. Bulk powders are very susceptible to spontaneous combustion because of deterioration, whereas TNT seldom deteriorates even under extreme storage conditions. If TNT were to be stored with the bulk powders, it would be necessary to assume that the TNT was equally as subject to spontaneous combustion because of deterioration. Were the powder to initiate, the TNT would also be lost simply because of the fact that it was stored with an item of ammunition which is more susceptible to deterioration.

Sensitivity of Initiation

Items of ammunition which are of an insensitive nature should never be stored with items of ammunition which tend to initiate readily, for example, TNT and blasting caps. TNT is very insensitive whereas blasting caps are of the other extreme. Were the TNT to be stored in the same magazine with the blasting caps, it would be necessary to assume that the TNT was just as sensitive as the caps, in that should the caps initiate, the TNT would in turn be set off.

Type of Packing

Items of ammunition packed in metal crates must not be stored in the same magazine with items which come in wood boxes. This is primarily a fire consideration in that should the wooden packing become ignited, the ammunition in the metal crates would be exposed to that fire.

Action in Case of Fire

If two items of ammunition require a different means of extinguishing them should they start burning, they should not be stored together. An example is white phosphorus filled items and small-arms ammunition. Burning small-arms ammunition is extinguished by means of water spray or fog. To extinguish white phosphorus, it is necessary to flood it with water. The application of spray or fog would tend to accelerate greatly the rate of burning as well as to cause the phosphorus to spread about the area.

Quantity of Explosives per Unit

Types of ammunition having a small quantity of explosive in a single item should not be stored with ammunition which has a large quantity of explosive in a single item, for example, demolition bombs and armor-piercing bombs. The demolition bomb contains approximately 50 per cent explosive filler whereas the armor-piercing bomb contains from 2 per cent to 15 per cent explosive filler. If the two items are stored together the armor-piercing bombs would needlessly be exposed to the large quantity of explosives in the demolition bombs.

Inert items of ammunition should never be stored with items of ammunition containing an explosive filler. Should the loaded items detonate, the inert items would be needlessly lost.

Application of Mixed Storage Regulations

The mixed storage regulations are in the form of ammunition mixed storage charts, which vary for different types of installations.

The chart shown in Figure 8-1 is particularly adapted for use on posts, camps and stations for it is designed to fit the needs of bases storing small quantities of ammunition and explosives and having limited storage facilities. This chart is also a great deal less restrictive than other charts. In cases where the actual explosive weight of the material being stored is less than one thousand pounds the chart permits a broad deviation from mixed storage principles.

Compliance with this chart is required on the majority of Air Force bases.

The chart shown in Figure 8-2 is designed primarily for use at ammunition depots or installations having large and varied stocks of ammunition supplies and extensive storage facilities.

3. MIXED STORAGE REGULATIONS UNDER FIELD CONDITIONS

General

Under field conditions, ammunition and explosives are stored in what are called "field storage units," rather than in standard ammunition magazines. A field storage unit is simply an outdoor area in which a specific type of ammunition is stored.

Field Storage Groups

For the purpose of determining what items of ammunition may be stored together within a single field storage unit, all items of ammunition and explosives have been divided into what are called "field storage groups," of which there are four.

Field Storage Group I. Approximately 85 per cent of the named items of military ammunition and explosives belong in this category. Therefore, rather than list the items, groups I, II, III, and IV are specifically defined and it is assumed that any item not mentioned as belonging to either group II, III, or IV will automatically belong to group I.

Field Storage Group II. All unfused, high-explosive bombs, aircraft mines and torpedoes and fused or unfused fragmentation bombs and fragmentation bomb clusters.

Field Storage Group III. All rockets regardless of filler.

Field Storage Group IV. Chemical fillers, including pyrotechnics and chemical ammunition of all types including gas, smoke and incendiary bombs.

When these categories of ammunition are stored, the storage is accomplished in field storage units.

4. QUANTITY-DISTANCE REGULATIONS

Purpose

The quantity-distance regulations indicate what quantities of various types of ammunition or explosives may be stored within a single ammunition magazine. They also indicate how far various quantities of these various types of ammunition must be located from inhabited buildings, public railways, public highways, and other ammunition magazines. This is accomplished by dividing all items of ammunition into twelve quantity-distance classes. All of the items belonging to one of these quantity-distance classes possess tha same degree of hazard.

Quantity-distance Tables

Figure 8-3 is an example of a quantity-distance table.

The hazards pertaining to particular classes of ammunition or explosives are the characteristics upon which the quantity-distance requirements for that class are based. The relationships between hazards and quantity-distance requirements for certain general classes are as follows:

Fire hazards. Fire is the most common hazard incident to the handling, and storage of ammunition and explosives. Small-arms ammunition, most pyrotechnics, and chemical ammunition for which no tables are shown also are considered fire hazards only as regards quantities and distances. Most other items of ammunition and explosives may, as

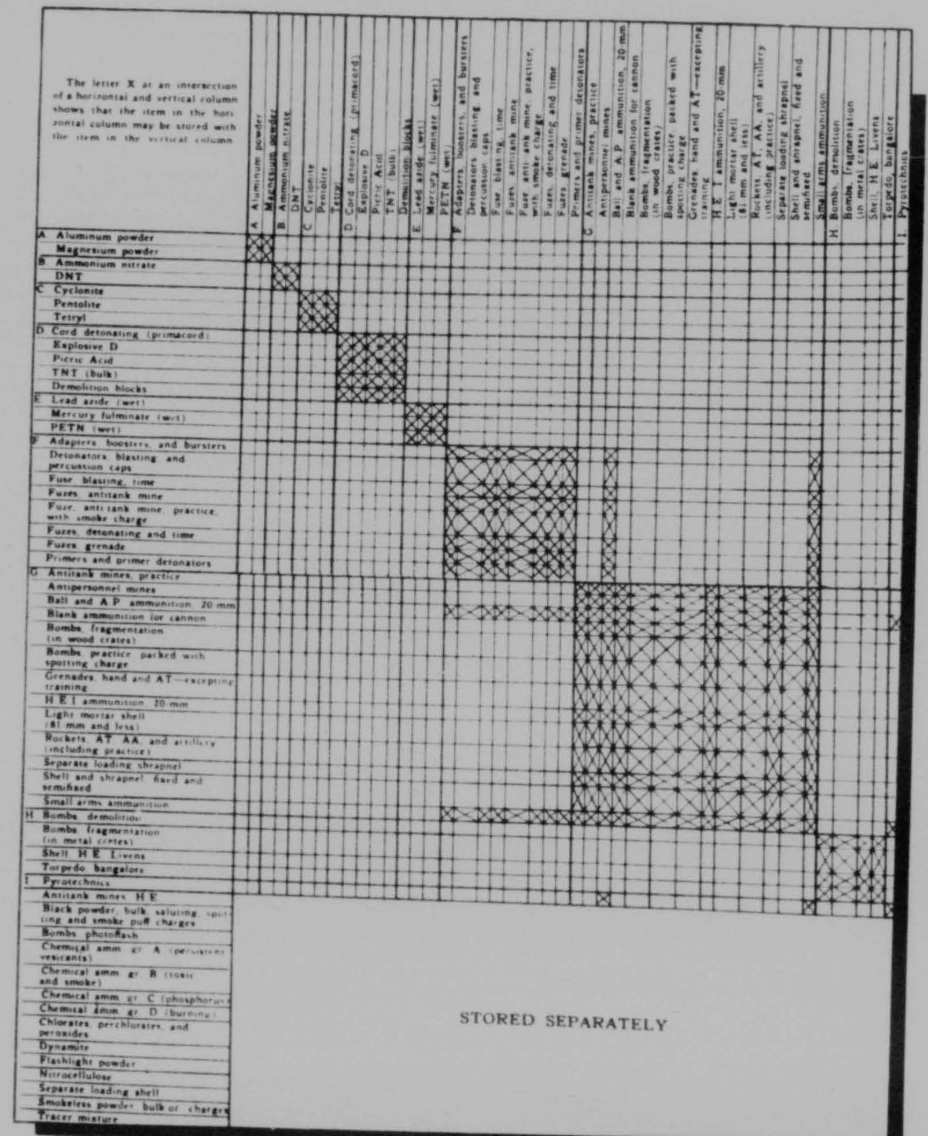

Figure 8—2. Storage Chart for Explosives and Ammunition.

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Quantity of explosives		Unbarricaded distance in feet from nearest—			
Pounds over—	Pounds not over—	Inhabited building [1]	Public railway [1]	Public highway [1]	Magazine [2]
	50	145	90	45	60
50	100	240	140	70	80
100	200	380	220	110	100
200	300	520	310	150	120
300	400	640	380	190	130
400	500	720	430	220	140
500	600	800	480	240	150
600	700	860	520	260	155
700	800	930	550	280	165
800	900	980	590	300	170
900	1,000	1,020	610	310	190
1,000	1,500	1,090	640	320	210
1,500	2,000	1,200	720	360	230
2,000	3,000	1,300	780	390	250
3,000	4,000	1,420	850	420	280
4,000	5,000	1,500	900	450	300
5,000	6,000	1,560	940	470	300
6,000	7,000	1,610	970	490	300
7,000	8,000	1,660	1,000	500	300
8,000	9,000	1,700	1,020	510	300
9,000	10,000	1,740	1,040	520	300
10,000	15,000	1,790	1,070	530	300
15,000	20,000	1,950	1,170	590	300
20,000	25,000	2,110	1,270	630	300
25,000	30,000	2,280	1,360	680	300
30,000	35,000	2,410	1,450	720	300
35,000	40,000	2,500	1,530	750	300
40,000	45,000	2,680	1,610	800	300
45,000	50,000	2,800	1,680	840	300
50,000	55,000	2,920	1,750	880	400
55,000	60,000	3,030	1,820	910	400
60,000	65,000	3,130	1,880	940	400
65,000	70,000	3,220	1,940	970	400
70,000	75,000	3,310	1,990	1,000	400
75,000	80,000	3,390	2,040	1,020	400
80,000	85,000	3,470	2,080	1,040	400
85,000	90,000	3,520	2,120	1,060	400
90,000	95,000	3,590	2,150	1,080	400
95,000	100,000	3,630	2,180	1,090	400
100,000	125,000	3,670	2,200	1,100	500
125,000	150,000	3,800	2,280	1,140	500
150,000	175,000	3,930	2,360	1,180	500
175,000	200,000	4,060	2,440	1,220	600
200,000	225,000	4,190	2,520	1,260	600
225,000	[3] 250,000	4,310	2,590	1,300	600

[1] American Table of Distances, requirements for bulk explosives.
[2] Magazine distances conforming with the requirements of paragraph 4: may be authorized under special conditions.
[3] Maximum permitted in any one magazine.

Figure 8–3. Quantity-Distance Table.

a result of fires, detonate and spread disaster to distances considerably in excess of fire-protection distances.

Sympathetic detonations. A sympathetic detonation is one which immediately follows as a direct result of an initial explosion. It may be the result of propagation, or it may be the result of missiles from the initial explosion. In any case, it is an explosion that so closely follows the initial explosion as to be indistinguishable from it.

Magazine-to-magazine Distances. The magazine-to-magazine distances for all classes of ammunition and high explosives are based on New Jersey State law. They are expected to give protection against propagation from explosions in adjoining buildings or magazines. It will be noted that these distances are in all cases substantially less than those required to protect inhabited buildings against structural damage. It is not expected that magazine-to-magazine distances will give protection against structural damage.

Missile Hazards. Explosions involving high-explosive bombs, or loaded-ammunition components introduce a hazard not normally present in commercial explosives. These hazards are missiles which may be projected either as pieces of broken-up bomb cases or other components, or complete bombs. Bombs may, and often do, explode upon impact or as a result of heating in fires. Missile distances prescribed in the quantity-distance tables for classes 3, 4, 5, 6, and 7 are based upon tests made at Aberdeen Proving Ground. They are based upon the distance within which most missiles will fall.

Concussion. The effects of the concussion produced by the detonation of explosives constitutes one of the most common hazards associated with explosives. The distances given in the tables for classes 8, 9, and 10 are expected to give protection against the concussion effect of explosions. They are identical with the American Table of Distances published by the Institute of Makers of Explosives.

Classes and Quantity-distance Tables for Military Explosives and Ammunition. The explosive contents of ammunition or components are shown on drawings, or the appropriate SNL's; if these are not available, the information desired should be requested from the Chief of Ordnance. The quantities shown in the tables herein were computed in the following manner:

a) For pyrotechnics the quantity is the gross weight of the boxes and contents.

b) For bombs the pounds of explosives are computed as follows: If a magazine contained 30,000 bombs, fragmentation, 90LB AN-M-82, the amount of explosives in the magazine is as follows: 30,000 × 13.5 = 405,000 pounds (13.5 is the approximate weight of the high explosives in the bomb).

When military explosives and ammunition are not packed in accordance with the provisions of approved drawings and specifications and SNL's, they will be stored in accordance with special instructions issued by the Chief of Ordnance.

When military explosives and ammunition are packed in accordance with the requirements of approved drawings and specifications and SNL's and are stored in accordance with storage drawings, they are classified as indicated below, and will be stored in accordance with the quantity-distance tables shown.

SMOKELESS POWDER IN CONTAINERS,[1] PYROTECHNICS, OR CHEMICAL AMMUNITION CONTAINING PHOSPHORUS

Quantity		Unbarricaded distance[2] in feet from nearest -			
Pounds over-	Pounds not over-	Inhabited building	Public railway	Public highway	Magazine[1,3]
100	1,000	75	75	75	50
1,000	5,000	115	115	115	75
5,000	10,000	150	150	150	100
10,000	20,000	190	190	190	125
20,000	30,000	215	215	215	145
30,000	40,000	235	235	235	155
40,000	50,000	250	250	250	165
50,000	60,000	260	260	260	175
60,000	70,000	270	270	270	185
70,000	80,000	280	280	280	190
80,000	90,000	295	295	295	195
90,000	100,000	300	300	300	200
100,000	200,000	375	375	375	250
200,000	300,000	450	450	450	300
300,000	400,000	525	525	525	350
400,000	500,000	600	600	600	400

[1] Smokeless powder in containers is intended to mean any smokeless powder stored in boxes, powder cans, cartridge storage cases, or any container used for the storage of smokeless powder.

[2] Unbarricaded distances as shown always will be used when considering above-ground magazines in which smokeless powder is stored. One-half the above distances are authorized for separation of igloo type magazines containing smokeless powder.

[3] Distances shown are applicable to operations succeeding the graining operation in smokeless powder plants.

Figure 8–4. Class 2—Quantity-Distance Table.

Class 1. Small-arms ammunition and mechanical time fuses without boosters. These materials are principally fire hazards. No limit is placed on the storage of small-arms ammunition.

Class 2. Smokeless powder, pyrotechnics, and chemical ammunition filled with phosphorus. These materials may become unsafe under extreme conditions of moisture and high temperature. They burn with intense heat.

Class 3. Point-detonating fuzes, minor caliber base-detonating fuzes, powder train and antitank-mine fuzes, packed separately in boxes; bomb fuzes, packed with fin assemblies. The amount of explosives in articles of this class, including the booster, varies from 30 to 500 grains, except in the case of bomb fuzes packed with fin assemblies, which contain a charge of approximately 1,000 grains. These fuzes usually explode progressively, not more than a box or two at a time. Pressures which would cause serious structural damage to adjacent magazines are not usually generated, and missiles are small and of light weight, usually falling within 300 feet. The quantity of fuzes stored in a single magazine will be kept to the minimum consistent with available

[1] These distances will not be reduced by barricades. One-half the above distances are authorized for concrete igloo magazines, except at the door end.
[2] Missile distance.
[3] Maximum permitted in any one magazine.

Quantity, pounds of explosives (not over -	Unbarricaded distance[1] in feet from nearest -			
	Inhabited Bldg[2]	Public Railway[2]	Public Highway[2]	Magazine
10,000[3]	400	400	400	300

Figure 8–5. Class 3—Quantity-Distance Table.

Quantity, pounds of explosives (not over-	Distance[1] in feet from nearest -			
	Inhabited Bldg[2]	Public Railway[2]	Public Highway[2]	Magazine
500,000[3]	1,200	1,200	1,200	800

[1] These distances will not be reduced by barricades. One-half the above distances are authorized for concrete igloo magazines, except at the door end.
[2] Missile distance.
[3] Maximum permitted in any one magazine.

Note Enclosure #4 Class 5

Figure 8–6. Class 4—Quantity-Distance Table.

Quantity, pounds of explosives not over -	Unbarricaded distance feet from the nearest - Inhabited Bldg[2]	Public R.R.	Public H'way[2]	Magazine
100,000	1500	900	450	300

[1]These distances will not be reduced by barricades. One half the above distances are authorized for concrete Igloo magazined except at the door end.

[2]Missile Distance

[3]Maximum permitted in one magazine

Figure 8–7. Class 5–Quantity-Distance Table.

storage capacity. The storage of more than 50,000 fuzes of any one model, or a total of more than 150,000 fuzes of all models in a single magazine will not be permitted except by specific authority.

Class 4. When packed in accordance with ordnance drawings and specifications: fixed and semifixed high-explosive shell (complete rounds), light-mortar ammunition, fragmentation bombs in wooden crates, grenades, and shrapnel of all calibers, fuzed or unfuzed, and blank ammunition for cannon. Articles in this class usually explode progressively, only a few boxes at a time, many explosions of individual rounds being of a very low order. Pressures which would cause serious structural damage to adjacent magazines are not usually generated, and most missiles would fall within 600 feet.

Class 5. Separate-loading shell of all calibers, loaded with explosive D, fuzed or unfuzed, and shell loaded with explosive D fuzed or unfuzed; and shell loaded with explosive D fuzed or unfuzed, not assembled to or packed with cartridge cases. These shells usually explode one at a time, and in practically all cases, with a low order. As only one shell should be involved in an explosion, the missiles are limited both as to number and range. Most of the missiles will fall within a distance of 1,200 feet.

Class 6. Major and medium-caliber base-detonating fuzes; bomb fuzes; adapters and boosters for high explosive shell, bursters for

of this Class are stored in igloo magazines the quantity and distance requirements prescribed for classes 9 and 10 will apply, except that no distances smaller than one-half the distances quoted in the above Class 6 Quantity-Distance Table are authorized.

[2]Missile distance.

[3]Maximum permitted in any one magazine.

Quantity, pounds of explosives (not over) -	Unbarricaded distance[1] in feet from nearest - Inhabited bldg[2]	Public Railway[2]	Public Highway[2]	Magazine
100,000[3]	1,500	900	450	300

[1]These distances will not be reduced by barricades. For concrete igloo magazines (except at the door end) one-half of the above distances are authorized. When items

Figure 8–8. Class 6–Quantity-Distance Table.

chemical shell, and for bombs, packed separately in boxes. The amount of explosives in single items of this class usually does not exceed one-half pound. They usually explode progressively, by piles. The number involved in any explosion is limited by making piles small and separating them by prescribed distances determined by actual detonation tests. Structural damage caused by the pressures generated usually is limited to adjacent magazines. The missiles are light and usually fall within 600 feet. The quantity of fuzes stored in a single magazine will be kept to the minimum consistent with available storage capacity. The storage of more than 50,000 fuses of any one model, or a total of more than 150,000 fuzes of all models in a single magazine will not be permitted except by specific authority.

Class 7. Separate-loading HE shell of all calibers, except shell loaded with explosive D. All in a magazine may explode but the explosion may be limited to one pile by arranging the material in accordance with instructions for piling separate-loading shell. Structural damage usually is limited to adjacent buildings. Most missiles will fall within 500 yards.

Class 8. Primers, detonators, primer-detonators for bombs, grenade fuses, and blasting caps, packed in accordance with Ordnance

Quantity, pounds of explosives not over	Unbarricaded distance[1] in feet from the nearest - Inhabited Building[2]	Public R.R.[2a]	Public Highway[2b]	Magazine
500,000	1800	1800	1800	300

[1]These distances will not be reduced by barricades. For concrete Igloo magazines (except at the door end) one half the above distances are authorized. when items of this class are stored in an Igloo magazine (except when segregated into piles in accordance with drawing No. 19-48-12) the quantity distance requirement for class 9 and 10 will apply except that no distance less one half the distance quoted in the above class 7 table are authorized.

[2]Missile Distance.

[3]Maximum permitted in one magazine.

[1]American Table of Distances, requirements for bulk explosives.

[2]Maximum permitted in any one magazine.

[a]One half of the above distances are authorized for concrete Igloo magazines except at the door end.

[b]Distances applicable to fragmentation bombs will not be less than those stated in the class 4 distance table.

Figure 8–9. Class 7. Quantity-Distance Table.

drawings and specifications. All in a magazine may explode at one time, but as the total amount of explosives involved is limited, structural damage usually is limited to adjacent magazines. This class of ammunition forms light missiles which have a very limited range.

Class 9. Flashlight powder, demolition blocks, spotting charges, black powder, bulk priming explosives; bulk initiating explosives such as tetryl, and bulk high explosives such as TNT and explosive D. Priming explosives such as mercury fulminate and lead azide will be stored in accordance with special instructions. In a fire, black powder usually explodes and TNT and explosive D usually burn, but may explode. Since these explosives are similar to the commercial explosives on which the American Table of Distances was based, they are stored in accordance with this table.

Class 10. Demolition bombs, fragmentation bombs in metal crates, or bundles, photoflash bombs, and HE antitank mines. All in a magazine may explode. In this case, structural damage will be limited to the distances specified for inhabited buildings in the American Table of Distances for similar quantities of commer-

Quantity, pounds of explosives (not over)	Unbarricaded distance in feet from nearest - Inhabited bldg[1]	Public Railway[1]	Public Highway[1]	Magazine
2,000	980	590	300	300
5,000	1,200	720	360	300
10,000	1,500	900	450	300
15,000	1,610	970	490	300
20,000[2]	1,740	1,040	520	300

[1]American Table of Distances, requirements for explosives in the form of blasting caps.

[2]Maximum permitted in any one magazine.

Figure 8–10. Class 8–Quantity-Distance Table.

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Quantity of explosives		Unbarricaded distance in feet from nearest-			
Pounds over -	Pounds (not over -	Inhabited Building[1]	Public Railway	Public Highway[1]	Magazine
--	50	145	90	45	60
50	100	240	140	70	80
100	200	360	220	110	100
200	300	520	310	150	120
300	400	640	380	190	130
400	500	720	430	220	140
500	600	800	480	240	150
600	700	860	520	260	158
700	800	920	550	280	165
800	900	980	590	300	170
900	1,000	1,020	610	310	180
1,000	1,500	1,060	640	320	210
1,500	2,000	1,200	720	360	230
2,000	3,000	1,300	780	390	260
3,000	4,000	1,420	850	420	280
4,000	5,000	1,500	900	450	300
5,000	6,000	1,550	940	470	300
6,000	7,000	1,610	970	490	300
7,000	8,000	1,660	1,000	500	300
8,000	9,000	1,700	1,020	510	300
9,000	10,000	1,740	1,040	520	300
10,000	15,000	1,780	1,070	530	300
15,000	20,000	1,950	1,170	580	300
20,000	25,000	2,110	1,270	630	300
25,000	30,000	2,260	1,360	680	300
30,000	35,000	2,410	1,450	720	300
35,000	40,000	2,550	1,530	760	300
40,000	45,000	2,680	1,610	800	300
45,000	50,000	2,800	1,680	840	300
50,000	55,000	2,920	1,750	880	400
55,000	60,000	3,030	1,820	910	400
60,000	65,000	3,130	1,880	940	400
65,000	70,000	3,220	1,940	970	400
70,000	75,000	3,310	1,990	1,000	400
75,000	80,000	3,390	2,040	1,020	400
80,000	85,000	3,460	2,080	1,040	400
85,000	90,000	3,520	2,120	1,060	400
90,000	95,000	3,580	2,150	1,080	400
95,000	100,000	3,630	2,180	1,090	400
100,000	125,000	3,670	2,200	1,100	800
125,000	150,000	3,800	2,280	1,140	800
150,000	175,000	3,930	2,360	1,180	800
175,000	200,000	4,060	2,440	1,220	800
200,000	225,000	4,190	2,520	1,260	800
225,000	250,000	4,310	2,590	1,300	800

Note Enclosure #5

Figure 8–11. Classes 9 and 10–Quantity-Distance Table.

cial bulk explosives, and most missiles will also fall within these distances. Quantities of class 10 explosives will be stored in accordance with the table for classes 9 and 10, except that the distances applicable to fragmentation bombs will not be less than those stated in the class 4 quantity-distance table; however, they may be one-half the distances as stated in the class 4 quantity-distance table when storage is in concrete igloo magazines; however, the door end is not considered barricaded.

Class 11. Chemical ammunition (except ammunition containing phosphorus). This ammunition is not considered an explosive hazard and no limit has been placed upon the storage of this material except that the storage must comply with the requirements for the storage of chemical ammunition.

Class 12. Explosives such as ammonium nitrate, TNT and wet nitrocellulose. These items are relatively insensitive and can be initiated

Maximum Quantity Per F.S.U.	800 tons
Maximum Quantity Per Stack	40 tons
Minimum Unbarricaded distance between stacks	50 yds.
Minimum Inter.F.S.U. distance	150 yds
Outside Safety distance	500 yds.

It will be noted in the information above that the maximum quantity per stack is 40 tons and that a distance of 50 yards is required between each of the 40 ton stacks. These are maximum figures. If it is desirable that stacks be smaller than 40 tons the distance required between them may also be reduced in accordance with Table I below.

Figure 8–12. Maximum Quantities and Minimum Distances for Field Storage.

only by means of a very intense detonation. When stored in an explosive area where there is a possibility that explosives might be projected into them, they will be stored like ammunition in class 9. When stored in an area with fire hazards and separated by inhabited building distance from areas containing ammunition and explosives, these materials may be stored in accordance with the requirements for smokeless powder which is class 2 ammunition.

5. QUANTITY-DISTANCE REGULATIONS UNDER FIELD CONDITIONS

Definitions

Inter F. S. U. Distance. These distances are those required between the nearest edges of adjacent field storage units, to keep one safe if the other should explode or catch on fire. This distance is comparable to the magazine distance indicated in quantity distance tables.

INTERSTACK DISTANCES FOR AMMUNITION IN FIELD STORAGE GROUPS I AND IV

Gross tons of Ammunition	Inter stack Dist. unbarricaded (yards)	Inter stack Dist. barricaded (yards)
10 or less	25 (min)	20 (min)
10-20	35	25
20-30	45	30
30-40	50	35
40 (max.)	50	35

It will be noted in the table above that there are barricaded distances indicated. It is very seldom that stacks of Group I and IV ammunition are barricaded because there is not sufficient space gained to warrant the labor necessary to erect the barricades.

Figure 8–13. Table I.

*Maximum Quantity per F.S.U.	100 tons, of explosive content
Maximum Quantity per stack	No requirement
**Minimum distance between stacks	No requirement Note Table II
Outside Safety Distance	500 yds.

*Just as in Quantity Distance Tables the quantity of bombs per stack is computed on the basis of the weight of the explosive content of the bombs rather than on the gross or overall weight.

**There is no required distance between individual stacks of aircraft bombs in that one bomb storage revetment generally constitutes a complete Field Storage Unit. It is assumed that should one stack of bombs detonate the entire contents of that unit will be lost. Were there sufficient distance left between individual stacks of bombs to render safe from one another they would occupy too much space.

Figure 8—14. Maximum Quantities and Minimum Distances for Field Storage.

Interstack Distance. This is the distance required between individual stacks within a single field storage unit.

Outside Safety Distance. This is the distance between a field storage unit and anything requiring complete safety from it. In the quantity distance tables inhabited building, public railroad, and public highway distances were the equivalent of the above described distance.

6. FIRE HAZARD

General

Many of the fires involving explosives and ammunition are preventable, for the causes have been well established and can, therefore, be anticipated and eliminated. It is the duty of all concerned in the handling of explosives and ammunition to study the causes of fires and thoroughly inform themselves of the safety precautions that must be taken to prevent them.

As fire-fighting facilities, organizations, and methods vary quite widely at the various establishments and are affected by local conditions, the general subject of fire prevention and fire fighting is covered by regulations and administrative orders.

Many of the general safety regulations are primarily for the prevention of fires. In addition thereto, certain special fire-preventive regulations are necessary and are contained in this section, being preceded by a brief discussion of the causes of fires. Their purpose is to explain and emphasize the importance of all safety and fire-prevention measures.

This section also contains regulations and advice as to fire-fighting facilities, organizations, and methods insofar as these differ from those ordinarily employed when stores of explosives and ammunition are not involved.

Causes of Fires

Fires in magazines and magazine areas in which explosives and ammunition are stored may result from several causes, of which the following are the most common:

Dry Grass, Leaves, and Underbrush. These may be ignited by sparks from locomotives, by smoking, or the careless use of matches and camp fires. Such fires often originate in areas adjacent to military establishments not

SAFETY DISTANCE (EDGE TO EDGE) FOR AMMUNITION IN FIELD STORAGE GROUP II

Tons of Bombs/FSU	Inter FSU distance, yds. Unbarricaded	Barricaded	Outside Safety Distance (yards)
20	100	25	500
30	120	30	500
40	135	33	500
50	150	37	500
60	160	40	500
80	180	45	500
100 (max.)	200	50	500
			500

(d) Maximum Quantities and Minimum Distances For Ammunition In Field Storage Group III

Maximum Quantity Per F.S.U.	800 tons
Maximum Quantity Per stack	40 tons
* Minimum Distance between stacks	35 yds.
Minimum Inter F.S.U. distance	500 yds.
Outside safety distance	1500 yds.

* This is a barricaded distance in that all stacks of rockets must be barricaded both front and rear.

Figure 8—15. Table II.

under the direct control of the commanding officer. If they are not detected and controlled, they may spread quickly and become uncontrollable.

Deteriorated Explosives and Ammunition. Explosives and ammunition deteriorate in storage. Normally, this deterioration occurs at such a slow rate that most explosives and ammunition remain serviceable for many years. However, under unfavorable storage conditions where the ammunition is subjected to abnormally high temperatures (above 80 F) or exposed to moisture for a prolonged period, the rate of deterioration is greatly accelerated. Practically all explosives and ammunition give off heat as they deteriorate but where the rate of deterioration is slow the heat thus generated is dissipated by conduction or radiation and no noticeable rise in temperature takes place. When deterioration becomes rapid, however, heat may be generated so fast that it cannot be thus dissipated and the temperature rises. This accelerates the deterioration still more until finally the temperature may become high enough to cause the explosive or ammunition to burst into flame. In certain cases where the explosive or ammunition is confined, an explosion or detonation may result.

Repacking, Renovation, and Salvage Operations not Properly Supervised and Conducted in Accordance with Recognized Safety Standards. The most common sources of trouble are excessive quantities of powder and loose explosives, accumulation of waste paper, broken boxes, etc.; failure to provide proper barricades and fire breaks where necessary to prevent the spread of fire.

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Carelessness or Violation of Regulations. Untrained personnel may cause fires by smoking, or striking matches in forbidden areas and buildings, or by tampering with explosives or ammunition, particularly grenades, fuzes, etc.

Failure to Understand and Observe Carefully the Safety Precautions Prescribed by Regulations for Destroying Explosives and Ammunition. The most frequent sources of trouble are flying fragments which cause grass fires or explode piles of explosives and ammunition awaiting destruction.

Failure to safeguard heating appliances, such as torches and furnaces used in making repairs to magazine roofs and magazines.

Lightning striking buildings, trees, or other objects in or near explosive areas.

Electric transmission lines, blown down or in contact with combustible materials.

Special Fire-prevention Rules

Fire prevention is of the utmost importance because of the difficulties encountered in controlling fires involving explosives and ammunition. The special fire-prevention rules set forth below are minimum requirements for establishments storing explosives and ammunition. They will be supplemented by such additional rules as the commanding officer deems necessary to secure adequate protection against fires at his establishment.

During the absence of the commanding officer, there must be present at the establishment a competent person to act for him in case of fire or other emergency.

The duties of guards, firemen, military personnel, and others must be so arranged that an adequate fire-fighting force is available at all times.

Ammunition personnel must be instructed thoroughly in the hazards due to fire and explosion, the safety precautions to be taken, and the means and methods to be used in preventing and fighting fires.

Fire drills and inspections must be conducted carefully to insure that all personnel understand their duties and that fire-fighting equipment functions dependably under actual working conditions.

All fire-fighting equipment, especially hand fire extinguishers, water barrels and buckets, and the supplies of auxiliary equipment, such as gunny sacks and brooms, must be inspected regularly as prescribed by the commanding officer. Any deficiences reported will be corrected promptly.

Repacking, renovation, salvage, and all operations involving the handling of explosives and ammunition, must be inspected regularly as prescribed by the commanding officer to see that the necessary fire-fighting equipment is present and in good working order

When explosives and ammunition are being handled, or work is being done in the immediate vicinity of such stores, there must be present, ready for immediate use, two chemical or other type hand fire extinguishers.

To combat grass or forest fires in or near magazine areas, there must be maintained at suitable locations an adequate supply of gunny sacks, brooms, rakes, hoes, or other similar equipment. It is good practice to provide a railway tank car, truck, or trailer equipped with a pump and fire hose for fighting fires in a magazine area. This equipment should be inspected regularly and protected against theft or unauthorized use.

Vegetation in the form of grass, undergrowth, weeds, etc., which is, or may become, a fire hazard, should be controlled by mowing, plowing, cutting, or, in calm weather and under adequate safeguards, by burning. Burning is not permitted within the fifty-foot space specified in the paragraph below, and brush, grass, wood, etc., in piles, may not be burned within two hundred feet of a magazine.

A fire break at least fifty feet wide and as free as practicable from combustible material, must be maintained around each aboveground magazine. The earth adjacent to, and extending over igloo magazines must not be cleared of vegetation other than dry debris.

The vegetation on and along railroad tracks must be controlled so that it will act as firebreaks.

In addition to those specified above, firebreaks around the entire magazine area and at other places within the magazine area should be maintained wherever necessary.

Keys to gates, magazines, and other buildings, which fire-fighting forces may enter, must be kept readily available at such places as the commanding officer may designate.

Fire-fighting Facilities

A fire involving explosives or ammunition may result in an intense conflagration or an explosion. Means for immediately attacking the first small blaze detected in a magazine or magazine area are vital, and reliance often must be placed upon hand equipment which can be maintained ready for immediate use. The following types of fire-fighting equipment may, under certain conditions, be used to good advantage and to supplement the regular fire-fighting facilities ordinarily maintained.

Water barrels and buckets placed at each magazine or at places specified by the commanding officer. If this class of fire-fighting equipment is always maintained so that it can be depended upon in case of fire, it is a valuable fire protection. However, in the summer time, the barrels must be frequently refilled, and in freezing weather, brine must be used. Buckets deteriorate rapidly unless they are painted frequently or protected from the weather, and sometimes they are blown about by wind storms if they are not fastened securely. Any device used for this purpose must be capable of being released at will.

Tank cars, trucks, or trailers may be filled with water and so located that they are readily available. Such protection, however, cannot be relied upon in freezing weather or when facilities for rapid movement to the scene of a fire are lacking.

Fire Fighting

To combat fires involving explosives and ammunition successfully, it is necessary that personnel understand thoroughly what a particular kind or class of explosive or ammunition will do when subjected to heat or flame. This section outlines in as much detail as possible what the experience has been with fires for the various classes of material, and also the general safety precautions to be observed in fighting the fire.

General instructions which should be followed in combating any fire involving explosives and ammunition are as follows:

When any person discovers smoke coming from a magazine, or sees other evidence that a magazine is on fire, he should give the alarm as quickly as possible. He will fail in his duty if he attempts to go into the burning building, as there is a possibility that he may be trapped and cannot give the alarm. When any person discovers a grass fire he immediately should give the alarm.

If the fire is small, and he is sure that he alone can extinguish it, he should do so at once.

Fire-fighting forces, when they arrive, should attack the grass fire vigorously even when it is close to a magazine.

In case a fire has actually gained headway in a magazine, fire-fighting forces must be warned not to endanger themselves in hopeless efforts to extinguish the fire, but to devote their efforts toward saving adjacent ammunition or buildings.

Methods of Combating Ammunition Fires

General. For the purposes of fighting or controlling ammunition fires all items of ammunition and explosives have been divided into four groups. These groups are called "fire hazard" or "fire symbol" groups. The four groups to which an item of ammunition will belong depend on the type of burning or explosive action and the degree of hazard in combating the fire. The burning and explosive actions are defined broadly as follows:

Deflagration. The building up of explosive power through a burning process, that is, an item of ammunition which is hazardous principally because of the fact that it burns.

Progressive Detonation. The uncontrolled, intermittent detonating of single items or packings within a stack, that is, all that is known is that the material will detonate. There is no knowledge of how many or when.

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Simultaneous Detonation. Mass detonation. This action will result in items having a high explosive filler.

Ammunition in Fire Symbol Group I constitutes the minimum degree of hazard and Group IV constitutes maximum hazard.

Fire Symbol Groups

Fire Symbol Group I. All ammunition belonging to quantity-distance classes I, II and 12.

Q.D. Class I. Small-arms ammunition except 20-mm H.E.I., small fuses w/o boosters and A.T. practice grenades.

Q.D. Class II. Chemical ammunition except ammunition containing white phosphorus.

Q.D. Class 12. Insensitive fillers such as ammonium nitrade and TNT, etc.

The above listed types of ammunition are hazardous primarily because of fire. Therefore, their action is that of deflagration. Burning small-arms ammunition and small fuzes will propel small, hot missiles which will carry for a distance of approximately two hundred yards. However, these missiles are a secondary problem as they have very little penetrating capacity. When the war gases are involved, all personnel should be equipped with complete protective clothing, particularly in the case of the vesicant gases. In case the fire involves only the toxic gases, a gas mask is sufficient. Symbol Group 1 fires are extinguished by means of applying a large volume of either water spray or fog. Should there be any H.C. smoke-filled items present it will be necessary to segregate them prior to applying the spray or fog as the effort to extinguish them will be ineffective and the material is liable to detonate. H.C. smoke must be drowned in water. In extinguishing a Symbol Group I fire it is also desirable to knock down the stacks. This tends to minimize the possibility of detonation.

Fire Symbol Group II. Quantity-distance class 3 ammunition.

Q.D. Class 3. Fuzes which contain from 30 to 500 grains of explosive material except in the case of bomb fuzes which come packed with fin assemblies which contain approximately 1000 grains of explosive material. Ammunition in this category detonates progressively. Explosions will occur and light, hot missiles will be propelled. Should it seem impossible to extinguish the fire, an effort should be made to localize it. The method of extinguishing this type of fire is the same as in the case of Fire Symbol No. 1.

Fire Symbol Group III. Quantity-distance class 2.

Q.D. Class 2. Fires caused by pyrotechnics are hazardous because of intense heat. Its hazard is therefore that of deflagration. This type of fire can be extinguished only when it is in an incipient stage. After the fire has progressed beyond the incipient stage, effort should be limited to the prevention of spreading. In order to extinguish pyrotechnic materials, it is necessary to smother them with some form of inert material such as dirt, sand, etc. Bulk dry cement is probably as effective an agent as any. A special talc is manufactured for the purpose of extinguishing pyrotechnic materials. The application of water to this type of fire will result in detonation. Care should be exercised to see that there are no carbon tetrachloride of carbon dioxide fire extinguishers in the vicinity of a pyrotechnics magazine as the application of either of these chemicals will result in poison gas.

White Phosphorus-filled Ammunition. To extinguish white phosphorus it is necessary to cut off all oxygen as phosphorus ignites spontaneously when exposed to oxygen. Phosphorus should be entirely submerged in water. Covering it with inert material would extinguish it but there would be no point in using this procedure in that removal of the inert material would result in immediate ignition. The application of water spray or fog will tend to accelerate the burning of the phosphorus and will cause it to be projected about the surrounding area. Normally it will burn in a mass.

Fire Symbol Group IV. Quantity-distance classes 4, 5, 6, 7, 8, 9, 10.

This fire symbol group contains all of the rest of the quantity-distance classes. These quantity-distance classes are made up of am-

munition containing high-explosive fillers and all of the bulk high explosives. It is imperative that every possible effort be made to keep a fire from spreading to ammunition in this category. Once the fire has reached this ammunition, personnel should retire to a distance of 1000 feet for each 50,000 pounds of material in the storage facility. This distance may be increased or reduced proportionally. These types of ammunition will detonate in mass, and effort should be limited to keeping the fire from spreading.

7. STACKING AND PILING

Ordnance Drawings

The 19 series of ordnance drawings is used as a guide to the proper methods of stacking and piling ammunition and explosives within standard ammunition magazines. Within the 19 series of ordnance drawings there is a complete blueprint of every type of packing for every type of military ammunition and explosives. The drawings contain the following specific items of information:

Maximum of specific items that may be stored in each of the three sizes of standard types of magazines.

Maximum explosive weight that may be stored in each of the three types of standard magazines.

Quantities and distances prescribed for individual stacks within a single magazine.

Dunnaging requirements.

Required aisle spaces within a single magazine.

General Rules for the Stacking and Piling of Ammunition and Explosives

Ammunition and explosives are to be segregated by type, caliber (in the case of bombs, weight will replace caliber), lot number, and type of packing.

Ammunition and explosives must be adequately dunnaged. Two inches of dunnage is the minimum accepted height for dunnage when ammunition is stored in magazines. When ammunition is stored under field conditions or out-of-doors, the minimum accepted dunnage height is four inches, however six inches is desirable.

Materials should be so stacked so as to assure that ample ventilation is available to all stacks and all parts of each stack.

Unless otherwise specified, on ordnance drawings, aisles are to be maintained so that units within a stack can be readily inspected, inventoried, or removed.

Whenever possible, lids, opening ends and bomb fuze cavities should face into an aisle.

Partially filled boxes or containers should be clearly marked and placed conspicuously in a stack.

Items should be placed in such a manner that the nomenclatures will be visible.

In magazines containing ammunition in quantity-distance classes 9 and 10, there should be no inflammable materials stored.

Compliance with quantity-distance regulations. Individual stacks. Stacks must be erected and kept in a stable manner. (A level stack is generally a stable stack. Stability can be determined by sighting a stack both vertically and horizontally.)

Outdoor stacks should be properly and adequately and in such a manner so that the ventilation to the stack is not cut off. This is accomplished by erecting a ridge pole across the top of the stack (tent like) with the tarpaulin extending outward from the sides of the stack so that there is approximately a foot of space between the bottom of the stack and the ends of the tarpaulin.

Wet or damaged ammunition containers should not be stacked. When repairing or replacing containers, care must be exercised to insure that all identifying markings have been transferred to the repaired or replaced container.

One should not "nest" aircraft bombs unless absolutely necessary. This practice is not only considered to be unsafe, but it presents a possibility of damaging suspension lugs and bomb bodies. It also is not conducive to safe and efficient bomb handling.

One must make sure that each end of each layer within a stack of bombs is securely blocked in place.

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8. STORAGE AND SURVEILLANCE OF SPECIFIC ITEMS OF AMMUNITION

Surveillance, General Information

The term "surveillance" as used herein includes the observation, inspection, investigation, and test of explosives and ammunition in storage and use; inspection of containers and buildings in which they are stored, and the inspection of facilities and methods used in storing, handling, shipping, maintaining, renovating, salvaging, and destroying explosives and ammunition.

The purpose of surveillance is to detect in stores of explosives and ammunition all conditions tending to increase deterioration or danger; to determine the state or nature of deterioration and the degree of serviceability, and to segregate seriously unstable conditions.

The Chief of Ordnance exercises general supervision over the surveillance of all explosives and ammunition in storage and service; prescribes the tests, technical methods of inspections to be made; and maintains records of the condition of all lots in service and storage.

Ammunition inspectors are personnel trained in the surveillance of explosives and ammunition. They are appointed and assigned by the Chief of Ordnance, but are under the control and supervision of the commanding officer.

Lot Numbers, Grades, and Packing Marking

General. Lot numbers are used in the identification of military explosives and ammunition. Except for certain unserviceable material, the lot number always appears upon the packing boxes or containers. It also appears on the data cards and in most cases upon the ammunition itself.

Lot numbers usually consist of letters and figures which represent the initials of the manufacturer or loading company, the number of the War Department procurement order, the serial number of the lot and, in some cases, the date.

The identification of military explosives and ammunition by lot number is essential for surveillance activities. It is the means whereby stocks are conserved or utilized to the best advantage, and defective or deteriorated ammunition is withdrawn from service. It is used also in selecting ammunition for issue, because the ballistics or performance of ammunition may vary from lot to lot.

Bulk High Explosives. A lot of TNT usually ranges from 5,000 to 100,000 pounds. As each lot has definite characteristics, its identity must be carefully maintained. A history of the manufacture of each lot is filed in the office of the Chief of Ordnance and is used in the investigation of any unusual action or deterioration occurring in service or in storage.

TNT is graded in accordance with United States Army Specification No. 50-13-5.

The containers used for packing bulk high explosives will comply with Interstate Commerce Commission regulations.

Small-arms Ammunition. The size of a lot of small-arms ammunition is determined by the quantity which may be manufactured conveniently, inspected, and tested under uniform conditions. An acceptable lot must exhibit uniform characteristics in acceptance tests. It may vary from a few thousand to a million rounds, but averages approximately half a million rounds. As each lot has definite characteristics its identity must be maintained. A lot number once assigned remains unchanged until the ammunition is expended.

All small-arms ammunition is not divided into lots. Caliber numbers for shotgun shell are designated as Lot 1, Lot 2, etc., followed by the year of purchase.

The term "cartridge lot" as well as "ammunition lot" has been used at times to identify small-arms ammunition. The latter name is preferred. The various systems that have been used in designating ammunition lots of small-arms ammunition are described in applicable technical regulations.

Lots of cal. .30, cal. .45, and cal. .50 ammunition designed for target practice or combat use in standard service weapons are assigned grades representing degrees of serviceability. The grades are determined by ballistic tests, surveillance tests, and reports of

performance from the using arms and services. Assignments to grades and changes therein are made by the Chief of Ordnance. A grade is usually assigned to an entire lot. However, portions of the same lot stored under different conditions may develop defects which would not apply to the entire lot. Different grades sometimes may be established for parts of lots at different places. Ungraded ammunition will not be issued or used for any purpose, but will be reported to the office of the Chief of Ordnance. The grades of ammunition are not marked on packing boxes or on slips inside the box; they are found only in ordnance field service bulletins.

Ammunition which is not used for target or combat purposes is not ordinarily graded; but special tests, both ballistic and surveillance, may be ordered by the Chief of Ordnance if at any time such ammunition appears to be unfit for storage or issue.

The various grades to which lots of cal. .30 and cal. .45, small-arms ammunition are assigned and described in field service bulletins and Army regulations.

Small-arms ammunition is packed in wooden boxes, practically all of which have metal liners. Each metal liner is made airtight and tested after it is packed. It should remain airtight unless subjected to rough handling. Most ammunition is packed in boxes which are made in accordance with Ordnance Department drawings. Other types of boxes are in use but will be discontinued when those now on hand have been expended. Cartridges are packed in containers in accordance with the methods described in appropriate technical manuals.

The details of marking and printing of small-arms ammunition containers may be obtained from the technical regulations governing small-arms ammunition.

Aircraft Bombs

Bombs are divided into lots varying in size from several thousand for the smaller types to a few hundred for large bombs. Each is marked with an ammunition lot number which is used to identify the lot when reporting evidences of deterioration or malfunctioning.

The present prescribed methods of packing bombs is as follows:

A detailed description of the packing boxes and crates, including details as to size and contents, will be found in technical regulations and on ordnance drawings and specifications. Spotting charges for practice bombs normally consist of a few pounds of black powder. These charges are stored, handled, and shipped under the regulations for black powder, with the exception that M1A1 spotting charges are not removed from their boxes but are stored as received.

Bombs, packing boxes, and crates for bombs are marked to show the size, lot number, filler, and other characteristics, including marking required by Interstate Commerce Commission regulations. The painting and marking of each type of bomb and its packing box or crate are described in applicable technical regulations. Bomb packing boxes which contain fuzes, or primer-detonators may be marked with a stripe of red paint to show the location of the fuze, or primer-detonator.

Fragmentation and chemical bombs are packed in metal tubes assembled in bundles (20 lb., M41), wooden boxes (25 lb., M3), or metal crates containing from two to five bombs each (30 lb., M5). Usually, fuzing components are packed in the same container.

One hundred-pound demolition bombs are packed in metal crates, one in a crate, or are packed as described below. The fuzes, primer-detonators, arming wire, swivel loop, and one fin brace for the 100-pound Mk IMI bomb will be inserted in a component metal box which will be assembled to the metal crate.

All demolition bombs except the 100-pound bomb are shipped without fins with metal shipping bands to protect the suspension lugs, and to facilitate handling. Fin assemblies are shipped separately from the bomb in wire-bound, veneer-wood, packing boxes. When shipments are made to using services, fuzing components are packed in a wire-bound accessory box which is inclosed in the fin-assembly box. In interdepot shipments, fuzing components are shipped in their respective boxes.

Fuzes, Primers, Boosters, and Detonators

Loaded components are divided into lots, and always will be identified by lot number. The size of a lot usually varies from 5,000 to 25,000 components and is dependent upon the stage of manufacture and other factors. Each lot is made and tested under uniform conditions and has certain characteristics which require that the identity of all components in the lot be carefully maintained. Where practicable, the lot number is stamped on the components, but it always appears on the containers in which they are packed.

Packing and Marking. The practice with respect to packing of those loaded components which are packed separately from the ammunition or bombs with which they are to be used, differs from one component to another, depending upon the character of the component. Provision is made for the packing of every item of issue to the field. Bomb fuzes which contain no explosives are packed in wooden boxes without metal liners, with the fuzes supported in trays to avoid their striking together. Bomb fuzes of more modern design, containing explosive components, will be shipped in individual containers within wooden boxes. Primers intended for assembly into complete rounds of ammunition are packed in paper cartons, waterproofed by dipping in paraffin, within hermetically-sealed metal liner, in wooden boxes. Primers for separate loading ammunition, that is, for issue to the field as primers, are packed in small metal boxes within wooden boxes. Adapter-boosters for bombs and adapters and boosters for artillery ammunition are packed in trays within unlined wooden boxes for shipment to loading plants. For detailed information regarding the method of packing each type of component, reference should be made to the proper drawing.

Safety Precautions. Fuzes, primers, boosters, and primer-detonators are loaded with explosives which are sensitive to shock and friction. Components of these types are supported in trays or racks, to protect them against shock, but they must be handled with care at all times. The covers of wooden boxes for these components are fastened with screws. Nails must not be used.

Pyrotechnics

Pyrotechnics for military use are divided into two general classes: illuminating and signaling. These two classes are further subdivided into pyrotechnics for ground troops and aviation pyrotechnics. Pyrotechnics are described in technical regulations, on ordnance drawings, and in specifications.

Pyrotechnics are divided into lots which represent a definite quantity that has been manufactured and tested under uniform conditions. The lot number usually appears on the individual pyrotechnics and on the containers.

Packing and Marking. Pyrotechnics are packed in metal-lined or unlined, nailed or wire-bound wooden boxes. Those in unlined boxes are packed in inner containers consisting of sealed, corrugated-board cartons, cylindrical fiber containers, or metal containers. The cartons are dipped in paraffin to protect the contents from moisture. The M8A1 aircraft flare is packed in an individual fiber container which in turn is inclosed in a single-flare, wire-bound box. The methods of packing pyrotechnics made during 1917-1918 are described in O.O. Form 2027, "Military Pyrotechnics"; for pyrotechnics manufactured since the war, they are described in technical regulations, on ordnance drawings, and in specifications. Pyrotechnics and their containers are labeled or marked to comply with Interstate Commerce Commission regulations and Army specifications and drawings. This marking includes the type or kind, date packed, lot number, and quantity. The M8A1 flares, their containers, and their packing boxes, are marked to indicate the date before which they must be expended.

9. STORAGE AND MAINTENANCE OF SPECIFIC ITEMS OF AMMUNITION AND EXPLOSIVES

Bulk High Explosives

Containers of high explosives are stored with the top side up to prevent the explosive

from sifting out. New stocks are piled, and existing stocks rearranged in compliance with applicable Ordnance Department drawings.

High explosives are usually very stable in storage, but their containers are subject to deterioration. Damaged or deteriorated containers must be repaired, or their contents transferred to new or serviceable containers. This work should be done in a room or building free from all other explosives or in suitable weather in the open, at sufficient distance to comply with quantity-distance table requirements, but in no case closer than 100 feet from any building containing explosives or ammunition. The amount of explosives at or near such operations must be limited to one open container of 100 pounds and four closed containers. Safety tools must be used for all repacking or repairing operations. The contents of damaged containers should be examined for the presence of dirt or foreign matter, which must be removed before repairing or repacking.

If a standard container is not available for repacking, a strong wooden box not exceeding 140 pounds gross weight when packed may be used. Such containers must be lined carefully as specified for the standard container. Containers must be marked to comply with Interstate Commerce Commission regulations.

Small-arms Ammunition

Small-arms ammunition is not an explosive hazard in storage, although under adverse conditions of storage it may become a fire hazard. With reasonable care in storage, and under the surveillance prescribed in these regulations, small-arms ammunition may be stored safely in any weatherproof magazine or warehouse. In small quantities it may be kept in a barracks storeroom. The conditions most likely to affect small-arms ammunition adversely are dampness, lack of ventilation, and extreme heat such as might be obtained in storing near steam pipes. If the atmosphere is damp or unusual temperatures are experienced, layers of boxes should be separated by dunnage to permit free circulation of air. Ammunition must be piled by lot, and each pile placarded to show readily the manufacturer, lot, caliber, and grade of the ammunition in each pile.

Small-arms ammunition in containers is piled and arranged in a magazine in accordance with instructions set forth in Army regulations and in ordnance drawings.

Maintenance activities in connection with small-arms ammunition include repairs to damaged containers, repacking, resoldering, and air testing containers. Ammunition which contains an excessive number of visible defects is sorted out to reclaim that which is still satisfactory for issue.

When damaged containers are repaired, or small-arms ammunition is repacked, the metal liner is sealed to protect the ammunition from deterioration. The apparatus use for air-testing smokeless powder containers is used if more suitable equipment is not available. A pressure of approximately two pounds per square inch is used. If the cover of the metal container is damaged, or is difficult to resolder, new covers must be requisitioned from the Chief of Ordnance. Ammunition must be repacked in the same manner as it was originally packed, unless the Chief of Ordnance issues specific instructions to the contrary. The identity of the ammunition must be maintained carefully by lot, and the markings on a repacked container must be a facsimile of those on the original container.

The sorting of lots of ammunition which cannot be issued because they contain an excessive number of visible defects, or the reclaiming and repacking of the serviceable ammunition in the lots must not be undertaken except upon specific instructions from the Chief of Ordnance. The process of reclaiming serviceable cartridges includes all of the operations necessary to remove defective cartridges and repack the ammunition for shipment. It involves removal of the ammunition from the old containers, culling out defective rounds, repacking serviceable cartridges into clips, bandoleers, cartons, etc., and resealing the metal container. New cartons, clips, bandoleers, covers for metal lines, etc., required for repacking must be requisitioned from the Chief of Ordnance. However, where practicable, the old containers, etc., must be used. When a lot of ammunition is reclaimed, it changes its lot number or grade only as specified in ordnance field service bulletins, except that defective cartridges culled from the lot are automatically classified as grade 3 ammunition.

Salvaging of small-arms ammunition consists of reducing the rounds to their principal components, such as cartridge case, bullet, and propelling charge. The method employed in breaking down the rounds will depend upon the facilities available, and any special instructions issued by the Chief of Ordnance. Since the principal hazard involved is that of fire, care must be taken to guard against an accumulation of powder at the breaking-down operations. Floors and benches must be kept clean, and powder from cartridges must be continuously removed from the immediate vicinity of breaking-down operations so that in case of fire not more than one or two pounds will be involved, and personnel will not be exposed to unnecessary hazards. Powder obtained from breaking-down operations should be placed in standard containers and stored in the open under tarpaulins or in a shed where a fire cannot cause great damage. Primers in cartridge cases usually are rendered inert by placing the cases in a fire. All salvaged components must be kept separate until disposed of in accordance with Army regulations or directions of the Chief of Ordnance.

Aircraft Bombs

In storing, a distinction is made between fragmentation and demolition bombs. Fragmentation bombs, when packed in wooden boxes like fixed ammunition, are not likely to detonate en masse if a fire occurs in the magazine.

Fragmentation bombs packed in metal crates are susceptible to mass detonation and must be stored in a manner similar to that specified for demolition bombs.

Demolition bombs have very thin walls. They are regarded as one of the most hazardous types of ammunition because of their tendency to detonate en masse if a fire occurs or a heated fragment is projected into the magazine in which they are stored. One of the most distastrous explosions on record originated from a fire in a magazine in which was stored a large number of demolition bombs packed in boxes. No feasible way of separating bombs or barricading piles of bombs in a magazine to reduce the hazard of mass detonation has been found. Safety can be obtained only by reducing the possibility of fire to an absolute minimum. Bombs should be stored in fireproof magazines without combustible dunnage.

To minimize the fire hazards, demolition bombs which may be packed in wooden boxes or crates must be removed therefrom before storing. Steel dunnage is preferred and must be used unless instructions to the contrary are issued by the Chief of Ordnance. Fuzes and primer-detonators must not be packed with bombs except in the case of metal-crated 100-pound bombs. Fuzes and primer-detonators may be stored with 100-pound bombs in igloo magazines.

Demolition bombs are so piled that fuze cavities can be readily inspected and visible signs of exudation detected. Bombs with fin assemblies attached are piled carefully to avoid damage to fin assemblies.

Bombs will be stored in those magazines which offer the best protection against fire and missiles. Approved, arch-type, earth-covered, concrete igloo magazines must be used if available.

Bombs in storage must not be fuzed or fitted with primer-detonators.

Maintenance activities include removal of rust, repainting, remarking, removal of exudate from the bombs and floors of the magazine, and repairs to containers. The removal of rust and repainting must not be done in a magazine in which explosives or ammunition are stored. These operations, however, may be conducted in an empty magazine, or in suitable weather in the open at sufficient distances to comply with intraplant quantity-distance requirements, but in no case closer than one hundred feet from any building containing explosives. Exudate is a dangerous fire hazard and must be cleaned from bombs and floors of magazines. When bombs are repainted the painting and marking must be a facsimile of the original painting and marking.

In renovation and salvage bombs may not be renovated, salvaged, or modified except with the specific approval of the Chief of Ordnance, who issues the necessary instructions for the performance of such work.

Fuzes, Primers, and Detonators

Components must be stored with the tops of the boxes up. Storing of all of one type in a magazine should be avoided, if possible, because a fire or an explosion may result in the loss of the entire quantity. In no case may more than 50,000 fuzes of any one model nor more than 150,000 of all models be stored in a single magazine. This prohibition does not apply to grenade fuzes, which are included in class 8 of military explosives and ammunition, with primers, detonators and like components. All boxes and containers opened for inspection must be resealed. They are piled in accordance with ordnance drawings. Incomplete boxes must be marked plainly for identification and placed on top of the piles. Open boxes of loaded components may not be stored in a magazine.

Maintenance includes repairs to containers, sealing and air testing of containers which have been opened for inspection. Containers opened for inspection must be resoldered or effectively resealed with adhesive tape. No work, such as removing rust, or repainting, may be done except by specific direction of the Chief of Ordnance, who will furnish the necessary instructions. Containers must not be opened or repaired in a magazine containing explosives or ammunition. This work must be done in a near-by empty magazine, in a repacking room, or during clear weather in the open at sufficient distance to comply with intraplant quantity-distance requirements, but in no case closer than one hundred feet from any building containing explosives.

In renovation and salvage, loaded components are to be renovated, salvaged, or modified only in accordance with specific instructions furnished by the Chief of Ordnance.

Descriptions of components such as fuzes, boosters, and primers are found in appropriate technical publications.

Pyrotechnics

Storage. Pyrotechnics are stored in containers as indicated in current ordnance drawings. Some pyrotechnics deteriorate rapidly in the presence of moisture and high temperature and may become unsafe. Good protection against moisture or dampnes and high temperature should be provided. Containers which show signs of dampness or moisture must be carefully examined; if the pyrotechnics have been damaged, they must be destroyed.

Only pyrotechnics in metal cases, such as aviation cartridges and airplane flares are reconditioned or renovated. Such work is done in accordance with specific instructions of the Chief of Ordnance.

Pyrotechnics should be protected against moisture, should be handled with care, and protected against shocks. The boxes should not be dropped or thrown. If pyrotechnics are exposed to moisture, they should be segregated from all other materials until an examination has been made to make sure that they are serviceable and are not dangerous.

10. DESTRUCTION OF EXPLOSIVES AND AMMUNITION

Explosives and ammunition which are dangerously deteriorated or which cannot be economically salvaged must be destroyed. Destruction of explosive material is accomplished by burning, exploding, or dumping at sea as specified in following paragraphs of this section. Burying explosives or ammunition, or dumping them into waste places, pits, wells, marshes, shallow streams or inland waterways is prohibited except for black powder and chemical ammunition.

Destruction must not be undertaken without prior approval of the Chief of Ordnance in each case, except that commanding officers may order the immediate destruction of dangerously deteriorated explosives or ammunition when in their opinion such action is necessary to protect life or property. When destruction is authorized, the provisions of Army Regulations 35-6640, "Lost, Destroyed, Damaged, or Unserviceable Property," will be observed.

Instructions for destroying duds are incorporated in appropriate technical and field manuals.

11. SPECIAL SAFETY REGULATIONS FOR THE DESTRUCTION OF EXPLOSIVES AND AMMUNITION

All dry grass, leaves, and other combustible materials must be removed within a radius of two hundred feet from the point of destruction. Fire-fighting facilities for combating grass fires should be maintained readily available and, if practicable, the ground at the point of destruction should be wetted down with water at the close of each day's operations.

Explosives and ammunition must not be destroyed by detonation if magazines and other buildings are in danger of being damaged by fragments or shock. If the distance from the place of destruction to magazines or buildings is less than eight hundred yards, a pit or trench which will limit effectively the range of fragments must be used.

Demolition of explosives may be accomplished either by the use of electric blasting caps with hand exploders (blasting machines) or by nonelectric blasting cups and safety fuze.

The signal for detonation will be given by one designated responsible individual only, who before each detonation will insure that all persons in the vicinity are protected by substantial cover, or have reached a safe distance. If a blasting machine is used, the wires must not be connected to the terminals until all personnel have reached cover.

If nonelectric blasting caps and miners' safety fuze are to be used the fuze must first be tested as follows: a piece of fuse twelve inches long is cut from the roll to be used and burned to determine the approximate time rate of burning in order that sufficient length of fuze will be used to permit all personnel to retire to a safe distance. The rate of burning of fuze varies with atmospheric conditions, degree of tightness of tamping, etc. Fuze which is too large in diameter to enter the blasting cap without forcing must not be used.

Electric blasting caps are exploded by an electric current. Nonelectric blasting caps are exploded by flame or sparks from safety fuse. Both types of caps are copper cylinders loaded with very sensitive and violent explosives and must be handled with extreme care. The use of improvised methods for exploding blasting caps is prohibited.

One-half pound TNT blocks, one-quarter or one-half pound blocks of nitrostarch explosives are provided for demolition purposes. These blocks must not be broken into smaller pieces.

Material to be burned must always be removed from containers as attempts to burn certain explosives or ammunition under even slight confinement may result in explosions.

The amount of material to be destroyed at one time must be kept at the minimum consistent with reasonable and safe operation. The number of units that may be destroyed safely at one time will be determined carefully by starting with a limited number and then gradually increasing that number until the maximum which can be destroyed without risks to life and property is determined.

As some types of ammunition are rather difficult to explode, a search of the surrounding grounds should be made after each blast and any dangerous material which has been thrown from the pit and not detonated should be collected and destroyed.

Material awaiting destruction must be protected against accidental ignition or explosion from fragments, grass fires, or burning embers. The base of supplies should be so isolated that if explosives should burn or detonate prematurely, surrounding property will not be damaged.

In repeated burning operations, care must be taken to guard against material being ignited from burning residue or heat retained in the ground.

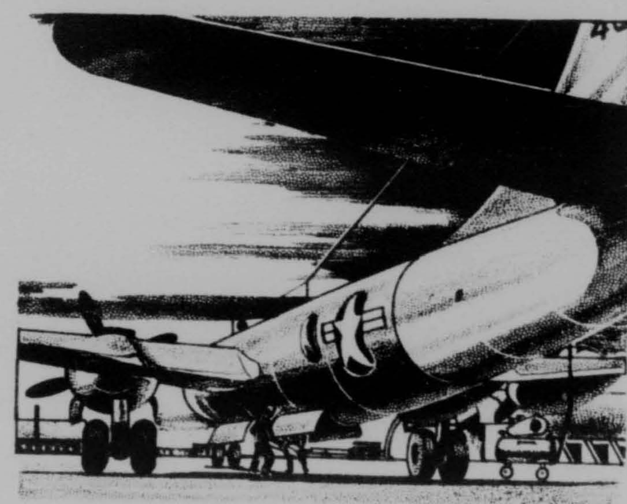
Sufficient and suitable protection for personnel must be provided in the form of temporary or permanent barricades, depending on local conditions. Necessary action must be taken to insure that barricades are used and safety distances observed by all persons. In cases of misfire, personnel must not approach

the pit, trench, or point of detonation until a period of thirty minutes has elapsed.

The destruction of ammunition by explosion or detonation requires very careful control by those in charge. Such work must not be attempted with inexperienced or untrained personnel. The number of employees engaged in such operations must be maintained at the minimum consistent with safety.

In the absence of specific regulations or information covering any phase of the destruction of explosive material, instructions must be requested from the Chief of Ordnance.

At establishments which are located near a deep-sea water-way, and which are too restricted in area to make burning or detonating safe, explosives or ammunition to be destroyed may be placed on barges, towed out to sea, and thrown overboard. In this case, however, the port authorities must be consulted, and their regulations regarding the transfer and disposal of material of this nature must be observed. The material is removed from containers before being dumped overboard. Instances are on record in which ammunition thrown overboard in heavy containers has washed up on shore from great distances and depths.



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AIR FORCE ARMAMENT

VOLUME I

CONTINENTAL AIR COMMAND

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VOLUME II

AIR FORCE ROTC

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CONTINENTAL AIR COMMAND

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Foreword

HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK
31 May 1949

ConAC Manual 50-11 Vol. II is published for the information and guidance of all concerned. It will be used in conjunction with the current program of instruction pertaining to Air Force ROTC Training.

BY COMMAND OF LIEUTENANT GENERAL WHITEHEAD:

GORDON P. SAVILLE
Major General, United States Air Force
Vice Commander

HEADQUARTERS — OFFICIAL — CONTINENTAL AIR COMMAND

OFFICIAL:

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Adjutant General

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THIS MANUAL SUPERSEDES ConAC Manual 50-140-1, Vols. I, II, III.

Preface

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THIS textbook has been prepared specifically for the college or university student who is participating in the Air Force ROTC program. It is one volume of a series designed to qualify him as an officer specialist in the United States Air Force.

The text is planned to indoctrinate the officer candidate in the fundamental principles of Air Force Armament, rather than to present a detailed treatise of the entire complex field.

In order to achieve maximum efficiency and effectiveness in the performance of his duties, the Air Force officer must be constantly aware of new developments in his specialty and its allied fields. A receptive mind, nurtured by supplementary research and reading, can be a vital force in the personal and professional development of the officer specialist throughout his career.

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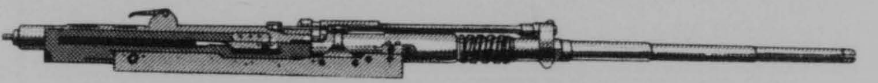
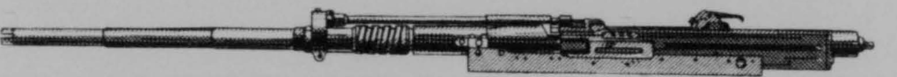
CHAPTER 1—20MM AUTOMATIC GUN



20 MM AUTOMATIC GUN M3—RIGHT SIDE VIEW



20 MM AUTOMATIC GUN M3—LEFT SIDE VIEW

SECTION I—DESCRIPTION

1. INTRODUCTION

The following chapter pertains to the nomenclature, identification, use, care, inspection and maintenance of the 20-mm automatic gun, M3 and allied equipment. Reference should be made to Air Force Regulation 50-13 concerning safety instructions and regulations for use of this weapon and firing ammunition in training, target practice, and combat.

2. GENERAL

The 20-mm automatic gun M3 is a combination blow-back and gas-operated aircraft weapon. It is air-cooled and has a cyclic rate of fire of from 650 to 800 rounds per minute. It is designed for fixed-position mounting in the wing or fuselage of an airplane or as a flexible gun in a turret. The gun can be fed from either right or left side.

Differences in Models

The differences between the 20-mm automatic guns AN-M2 and M3 which affect troop use are shown in Figure 1-1.

Serial Numbers

The gun serial number is stamped on the receiver. (See Figure 1-2).

The tube serial number is stamped on the tube just ahead of the gas cylinder bracket.

3. CRADLE GROUP

The gun is mounted in a cradle assembly which is so designed as to allow the gun to move backward in recoil and forward in counter-coil. The nonrecoiling recoil housing assembly of the gun, which fits around the recoiling gun tube, is secured to the mounting bracket of the cradle by means of two trunnion blocks and four trunnion block and mounting bracket screws safetied by a plate, the corner of which is bent up. The receiver, which is recoiling, engages one horizontally rotating roller and two vertically rotating rollers at the rear of the cradle. The rollers carry the weight and control the vertical movement of the gun. (Figure 1-3).

The cradle also mounts the anchor support bracket to which the magazine slide is fixed by means of a magazine slide anchor. In this manner the magazine slide is made nonrecoiling, whereas the receiver, on which it is mounted, recoils during firing. This condition is utilized in the operation of the 20-mm feed mechanism AN-M2 which is recoil operated.

The sides of the cradle are drilled and tapped for mounting the various chargers.

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20-mm Automatic Gun M3	20-mm Automatic Gun AN-M2
Right- or left-side charging, using following charges: 20-mm manual charger M6 20-mm pneumatic charger M4 20-mm hydraulic charger M7 20-mm hydraulic charger M5	Right-side charging only, using following charges: 20-mm manual charger M2. 20-mm hydraulic charger M1.
Left- or right-side feeding, using 20-mm feed mechanisms AN-M2, M3, and AN-M1A1. 20-mm electric triggers AN-M1A1 and AN-M4.	Left- or right-side feeding, using 20-mm feed mechanism M3, AN-M1A1. Manual firing, using 20-mm sear mechanism M1; 20-mm electric trigger AN-M1.

The differences between the 20-mm automatic guns AN-M2 and M3 which affect ordnance maintenance are as follows:

20-mm Automatic Gun M3	20-mm Automatic Gun AN-M2
Gas cylinder bracket can be removed for replacement or for cleaning. Rear buffer is lubricated at assembly; it is not to be disassembled bur replaced as a unit. Length of tube is 52.5 inches.	Gas cylinder bracket is shrunk on and pinned in place. Rear buffer can be disassembled for cleaning or replacement. Length of tube is 67.5 inches.

Figure 1—1. Comparative Features of 20-mm Automatic Gun M3 and AN-M2.

4. TUBE AND RECEIVER GROUP

General

For the purposes of description, disassembly, and assembly, the following components are treated as parts of the tube and receiver group:

Gun tube
Receiver
Rear buffer and driving spring guide
Magazine slide

Gun Tube

The tube serves to accommodate the front mounting arrangements, recoil housing, and the gas cylinder sleeve group (Figure 1-4).

The threaded muzzle end is for attaching the flash hider (Figure 1-5). The threads to the rear of the threaded muzzle end serve for attaching certain types of British mounts but are not used for mounting the gun in U.S. airplanes. When these threads are not in use, they are protected by a thread protector sleeve and cap.

Receiver

The receiver houses most of the working parts. (Figures 1-6 and 1-7)

The front of the receiver is threaded internally to receive the tube.

A guideway on each side of the opening on top of the receiver accommodates the magazine slide by means of which the feed mechanism is secured to the gun.

The rear of the receiver has vertical dovetail grooves for attaching the rear buffer.

The rear underside of the receiver accommodates the sear mechanism.

The front underside of the body is open to permit ejection of empty cartridge cases. Above the ejector opening are two receiver slides which are bolted to the sides of the receiver and serve to support the breechblock in its forward movement. The slides have cammed surfaces at the rear which engage corresponding cams on the breechblock lock, to cam it into the locked position with the assistance of the camming action of the

GENERAL DATA	
Weight of gun, including cradle	99.5 lb.
Over-all length of gun	77.7 in.
Weight of the tube	26.2 lb.
Length of the tube	52.5 in.
Muzzle velocity	2,730 ft per sec.
Rate of fire	650 to 800 rounds per min.
Rifling:	
Number of grooves	9.
Depth of grooves	0.015 in.
Width of grooves	0.205 in.
Width of lands	0.068 in.
Twist, uniform, right-hand, slope	7 deg.
Length	48.06 in.
Travel of projectile in tube	48.66 in.
Feed Mechanism. 20-mm feed mechanism AN-M2.	
Weight	13 lb.
Over-all length	10.2 in.
Maximum extension:	
Above centerline of gun (LH and RH feed)	5.5 in.
To right to centerline of gun (RH feed)	3.[illegible]2 in.
To left of centerline of gun (RH feed)	[illegible].5 in.
To left of centerline of gun (LH feed)	3.[illegible]2 in.
To right of centerline of gun (LH feed)	[illegible].5 in.
20-mm feed mechanism M3.	
Weight	1[illegible].5 lb.
Over-all length	18 in.
Maximum extension:	
Above centerline of gun (LH and RH feed)	4.81 in.
To right of centerline of gun (RH feed)	3.87 in.
To left of centerline of gun (RH feed)	4.18 in.
To left of centerline of gun (LH feed)	3.87 in.
To right of centerline of gun (LH feed)	4.18 in.
Motor	24 v, dc, 7,600 rpm, 4.6 lb-in. torque.
Electric Triggers. 20-mm elec. trigger AN-M1A1.	
Weight	5 lb.
Volts	24 v, dc.
Pull	(approx) 70 lb.
20-mm elec. trigger AN-M4.	
Weight	3.5 lb.
Volts	24 v, dc.
Pull	(approx) 70 lb.
Chargers. 20-mm pneumatic charger M4.	
Weight	2.5 lb.
Length	23.2 in.
Operating pressure	800 lb.
20-mm manual charger M6.	
Weight	3 lb.
Length	19.2 in.
20-mm hydraulic charger M5.	
Weight	4.3 lb.
Length	26.5 in.
Operating pressures	1,200 lb.
20-mm hydraulic charger M7.	
Weight	2.8 lb.
Length	24 in.
Operating pressures	1,000 lb.
20-mm Electric Heater M1.	
Weight	1 lb.
Power	200 w.
Volts	24 v, dc.

Figure 1—2. General Data 20-mm Automatic Gun.

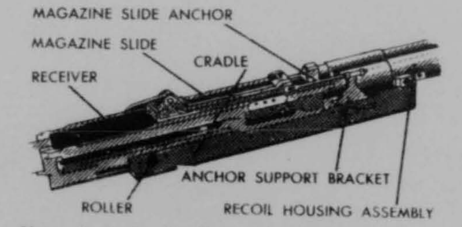

Figure 1—3. Cradle (Assembled to Gun).

breechblock slides. At the rear of the ejector opening, a transverse slot is cut in each side of the receiver body to accommodate the breechblock locking key. The breechblock locking key engages the breechblock lock when the lock is cammed down into the locked position.

The cradle mounting plate on the middle of the underside of the receiver serves to support the gun and control its vertical movement by means of rollers fitted in the gun cradle.

The electric heater is installed on the breechblock locking key and receiver slides.

5. REAR BUFFER AND DRIVING SPRING GUIDE

General

The function of the rear buffer is to cushion the shock of the rearward movement of the breechblock, and to start the breechblock on its forward movement. This action is accomplished by a series of ring springs guided by a sleeve, and a coil spring placed inside the sleeve.

As the breechblock moves to the rear, it compresses the driving spring; this absorbs much of the inertia of the breechblock. As the breechblock hits the rear buffer, it transmits the shock of recoil to the springs. The springs absorb the remaining shock and bring the breechblock to a stop. At this time, expansion of the rear buffer springs and the driving spring forces the breechblock forward.

Removal

With a blunt chisel, the rim of the driving-

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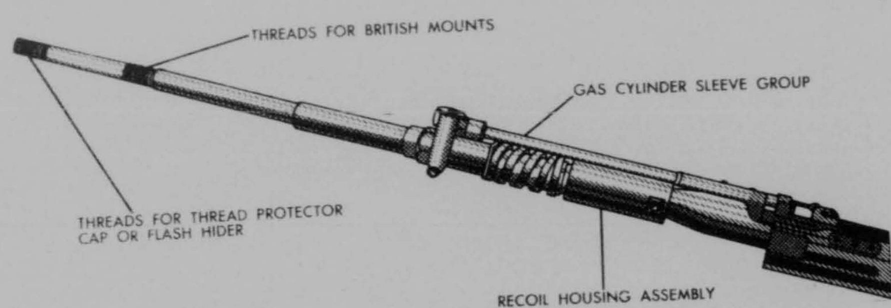


Figure 1—4. Gun Tube Showing Components Mounted on Tube—Close-Up View.

spring guide retainer is straightened so that it does not engage the driving-spring guide head (Figure 1-8). Similarly, the driving-spring guide-cap lock plate is disengaged from the cap (if one is used), the cap is unscrewed, and the plate removed.

The driving-spring assembling tool is inserted through the driving spring guide head and the tool pushed forward until it engages the driving-spring guide plunger.

The driving-spring guide-sleeve assembly is unscrewed with the special rear buffer wrench. The guide with the driving spring and plunger is removed (Figure 1-9).

The rear buffer-lock plunger is retracted and the rear buffer group removed by sliding it out of the dovetail grooves in the receiver.

The driving-spring guide retainer must be kept with the rear buffer.

Note: Disassembly of the rear buffer is prohibited.

6. MAGAZINE SLIDE

General

The magazine slide has a guide on each side which provides for sliding engagement with corresponding guideways on the receiver. The feed mechanism is secured to the magazine at the front by two hook-shaped projections on the slide, and at the rear by the magazine slide latch. (Figure 1-10).

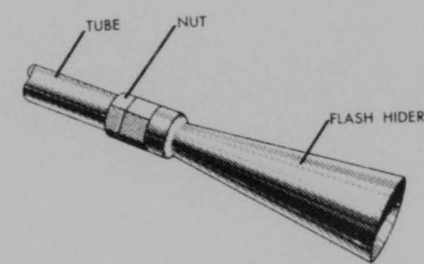


Figure 1—5. 20-mm Flash Hider M4 Installed on Gun Tube.

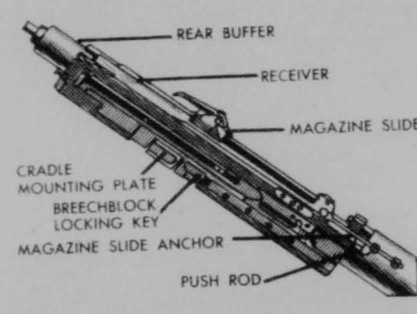


Figure 1—6. Receiver—Top Right View.

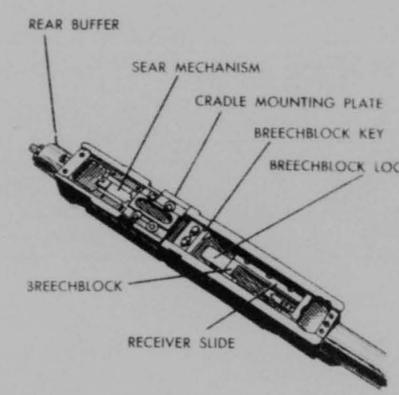


Figure 1—7. Receiver—Bottom View.

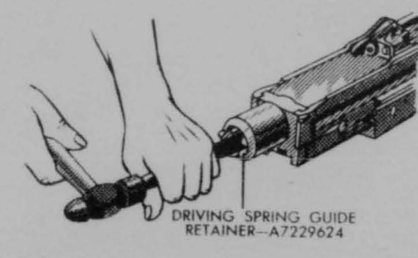


Figure 1—8. Straightening Driving Spring Guide Retainer.

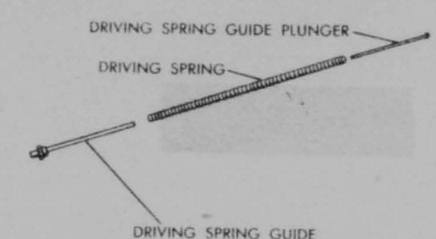
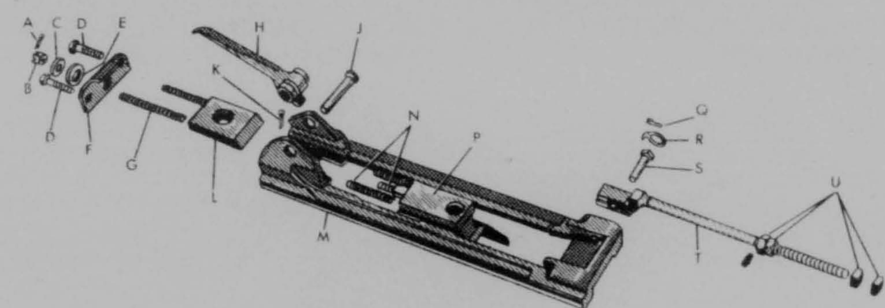
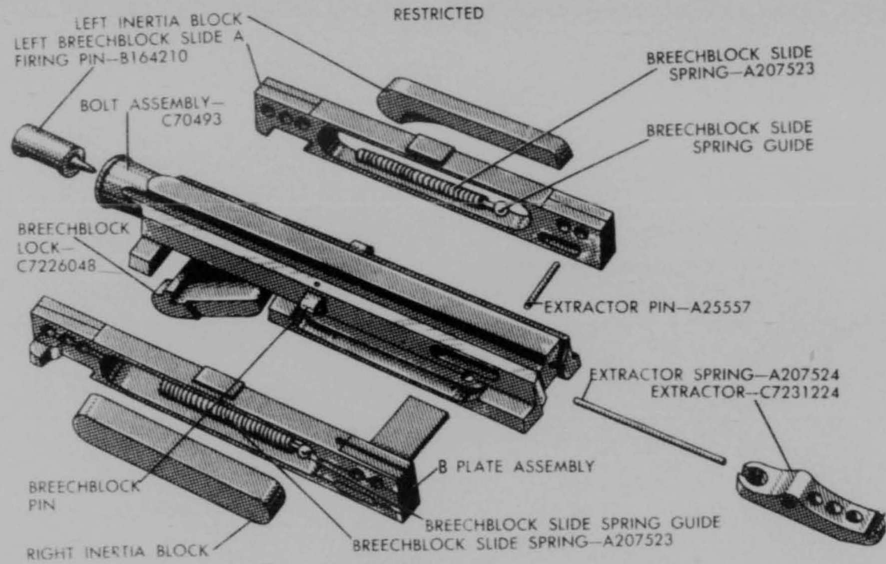


Figure 1—9. Driving Spring Guide and Plunger.



A. COTTER PIN—137142
B. EJECTOR STUD NUT—A25843
C. EJECTOR STUD NUT WASHER (STEEL)
D. MAGAZINE SLIDE LOCK PLATE SCREWS
E. EJECTOR STUD WASHER (FIBRE)
F. MAGAZINE SLIDE BACK PLATE
G. MAGAZINE LATCH SPRINGS
H. MAGAZINE SLIDE LEVER
J. MAGAZINE SLIDE LEVER PIN
K. COTTER PIN—137142
L. MAGAZINE LATCH
M. MAGAZINE SLIDE
N. EJECTOR SPRINGS—A25846
P. EJECTOR—B7229942
Q. COTTER PIN—137142
R. ANCHOR SCREW LOCK WASHER—A25613
S. ANCHOR SECURING SCREW—A25607
T. MAGAZINE SLIDE ANCHOR
U. MAGAZINE SLIDE ANCHOR NUTS—218564

Figure 1—10. Magazine Slide Parts.



A & B COMPRISE BREECHBLOCK SLIDE ASSEMBLY (MATCHED)—7229969

Figure 1–11. Breechblock Parts.

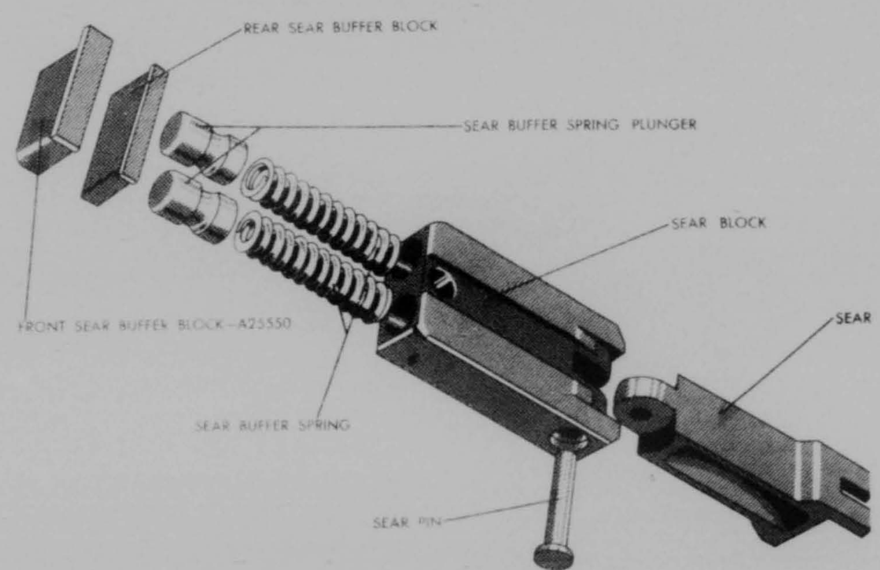
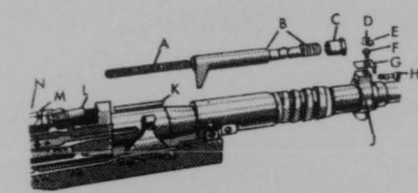


Figure 1–12. Parts of Sear Mechanism.



A GAS CYLINDER SLEEVE SPRING
B GAS CYLINDER SLEEVE AND PISTON
C GAS CYLINDER
D 041 LOCKING WIRE
E GAS CYLINDER GUIDE LOCK WASHER
F GAS CYLINDER BRACKET PLUG—B163320
G GAS CYLINDER LOCK PLATE
H GAS CYLINDER VENT PLUG—B7229626
J GAS CYLINDER BRACKET
K GAS CYLINDER SLEEVE PUSH ROD
L GAS CYLINDER GUIDE
M GAS CYLINDER LOCK WASHER
N COTTER PIN—137142

Figure 1–13. Parts of Gas Cylinder Sleeve Group.

The ejector fits into the lower two grooves in the magazine slide beneath the latch. It has two prongs projecting from a steel plate. The upper, inner surfaces of the prongs are shaped to center the incoming round into the path of the breechblock as it moves forward. The top shoulder of the breechblock moves between the two prongs of the ejector which deflect the empty cartridge case downward as the breechblock moves to the rear.

The slide is connected by the magazine slide anchor and anchor support bracket to the cradle; it is, therefore, fixed while the gun recoils during firing.

7. BREECHBLOCK GROUP

General

The function of the breechblock group is to carry the round from the mouth of the feed mechanism into the chamber, fire the round, extract and eject the empty case, and support the case until it is deflected out of the receiver by the ejector. (Figure 1-11).

Figure 1–14. Recoil Group.

Sear. The sear mechanism is a part of the breechblock. Component parts of the sear mechanism are illustrated in Figure 1-12.

8. GAS CYLINDER SLEEVE GROUP

General

The function of the gas cylinder group is to unlock the breechblock so that it can be forced back by straight blowback action. (Figure 1-13).

9. RECOIL GROUP

General

The function of the recoil group is to absorb the shock of recoil of the gun and return it into battery. (Figure 1-14).

SECTION II—DISASSEMBLY AND ASSEMBLY

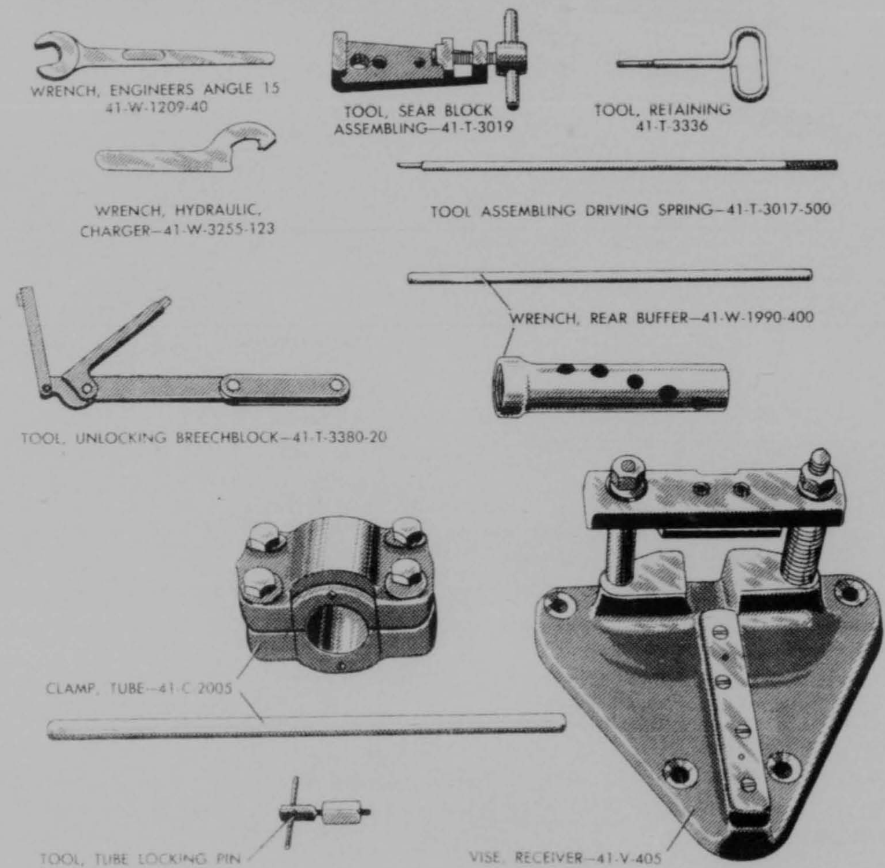


Figure 1—15. Tools for Automatic Guns M3.

1. SPECIAL TOOLS

Special tools used for the 20-mm automatic gun M3 are illustrated in Figure 1-15.

2. CRADLE GROUPS

Removal

The two front magazine slide anchor nuts are unscrewed (Figure 1-16) and the magazine slide moved to the rear as far as it will go.

The locking plate is removed and the two trunnion-block and mounting-bracket screws on each side of the gun are unscrewed. (Figure 1-16). The two trunnion blocks are then removed.

The cradle is moved forward until the magazine slide anchor bracket clears the magazine slide anchor. The cradle is slipped to the

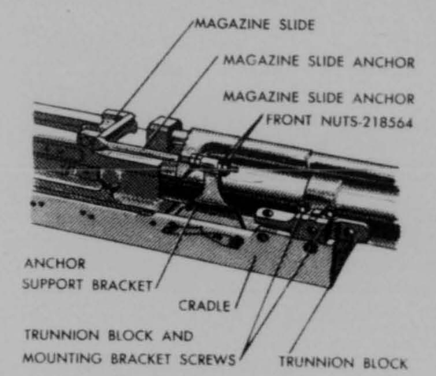


Figure 1—16. Removal of Cradle.

rear and removed from the gun.

The locking wire is removed and the two anchor support bracket screws are unscrewed to disconnect the anchor support bracket (Figure 1-17).

Note: Further disassembly of the cradle is prohibited.

Installation

The cradle is moved from the rear onto the gun as far as it will go, the rollers on the cradle engaging the cradle mounting plate.

The cradle is moved slightly rearward so that magazine slide anchor will recess into the anchor support bracket. The two anchor front nuts are then replaced.

The two trunnion blocks are replaced so that they engage the trunnion adapter, and so that lugs on blocks fit into slots in the mounting bracket. Slotted vertical flange of block should point toward muzzle (old-type blocks have one flange; new-type blocks have a flange at each end).

The locking plates are replaced, the trunnion block and mounting bracket screws are screwed in and secured by bending up the corners of the plates.

The anchor support bracket is secured to the inside wall of the cradle by means of the two anchor-support bracket screws which are lock-wired. The bulging side of the bracket should point toward inside of cradle.

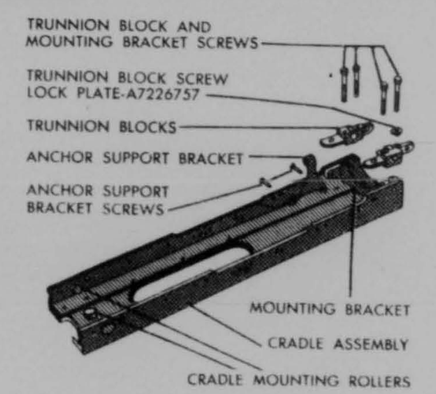


Figure 1—17. Parts of Cradle.

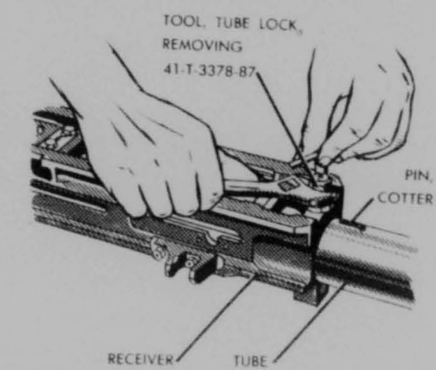


Figure 1—18. Removing Tube Locking Pin.

3. TUBE AND RECEIVER GROUP

Removal and Installation

A gun tube is replaced by first removing the cradle and then the gas cylinder sleeve group. The cotter pin is extracted and the tube locking pin removed with a tube-lock removing tool (41-T-3378) (Figure 1-15).

The receiver is placed in a receiver vise (41-V-405) as shown in Figure 1-15, and clamped securely.

The tube clamp (41-C-2005) (Figure 1-15) is installed over the tube as close to the receiver as possible.

The tube is unscrewed and the threads in the front of the receiver are cleaned.

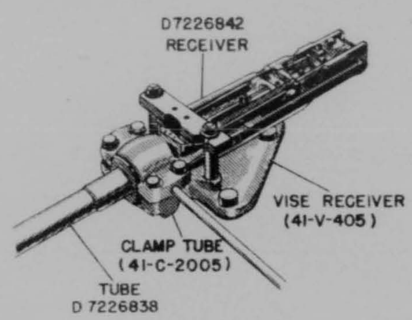


Figure 1—19. Replacing Tube.

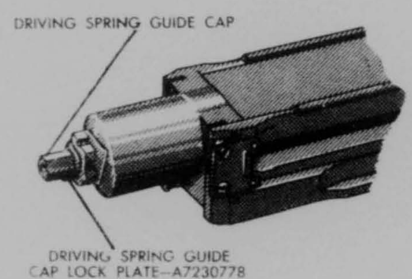


Figure 1—20. Removal of Driving Spring Guide Cap and Cap Lock Plate.

Before installing a new tube, the threads are examined and coated with a light film of graphited grease (light) to aid in assembly.

The tube is installed and the hole in the receiver aligned with the hole for the tube locking pin.

A 25/64-inch hole is reamed in the tube.

The tube locking pin is installed and secured with a cotter pin. (Figures 1-18 and 1-19).

4. REAR BUFFER AND DRIVING SPRING GUIDE

Removal

The rim of the driving spring guide retainer is straightened with a blunt chisel so that it does not engage the driving spring guide head (Figure 1-8). Similarly, the driving spring guide cap lock plate is disengaged from cap (if used), the cap is unscrewed and the plate removed (Figure 1-20).

The driving spring assembling tool is inserted through the driving spring guide head, the tool being pushed forward until it engages the driving spring guide plunger (Figure 1-21).

The driving-spring guide-sleeve assembly is unscrewed with a special buffer wrench. The guide is removed along with the driving spring and plunger (Figure 1-9).

The rear buffer lock plunger is retracted and the rear buffer group removed by sliding it out of the dovetail grooves in the receiver (Figure 1-22).

The driving spring guide retainer must be kept with the rear buffer.

Note: Disassembly of rear buffer is prohibited.

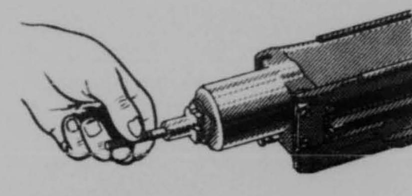


Figure 1—21. Inserting Driving Spring Guide Assembling Tool.

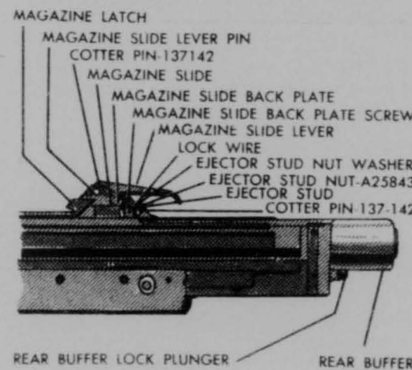


Figure 1—22. Removal of Rear Buffer and Magazine Slide.

Installation

The rear buffer is slipped up in the dovetail grooves of the receiver.

The rear buffer lock plunger is retracted and the buffer moved upward until the plunger snaps into position in the slot in the receiver.

The driving spring retainer (old-type) is positioned on the rear buffer so that pin on the retainer fits into hole on rear buffer. The new-type retainer does not have a pin, instead it has a flange which fits under rear buffer.

The split end of the driving spring assembling tool is inserted into the driving spring guide plunger and the driving spring placed over the tool and plunger. The driving spring guide is inserted into the driving spring so that it fits over the tool.

The assembled unit is then inserted into the receiver through the opening of the rear buffer, sliding into the bore of the breechblock (Figure 1-23).

The rear buffer wrench is placed on the guide, which is pressed in until it contacts the rear buffer; the tool is then turned to screw the guide into the buffer.

The rim of the retainer is bent on a flat of the guide.

The cap lock plate (if used) is assembled on the guide, the cap is screwed onto the guide, and the rim of the plate is bent on a flat of the cap.

5. MAGAZINE SLIDE GROUP

Disassembly (Figure 1-24)

The two magazine slide anchor front nuts are unscrewed; the rear buffer is removed and the cotter pin is removed from the ejector stud.

The ejector stud nut is unscrewed, and the ejector withdrawn, taking care not to lose the two ejector springs.

The ejector stud nut washer (steel) and ejector stud washer (fiber) are removed.

The lock wire and the magazine slide backplate screws are removed, keeping the screws even.

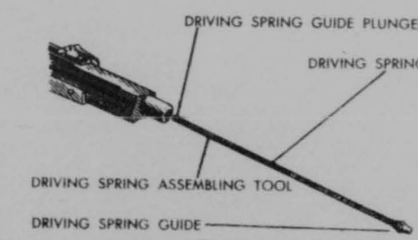


Figure 1—23. Inserting Driving Spring, Guide, and Plunger.

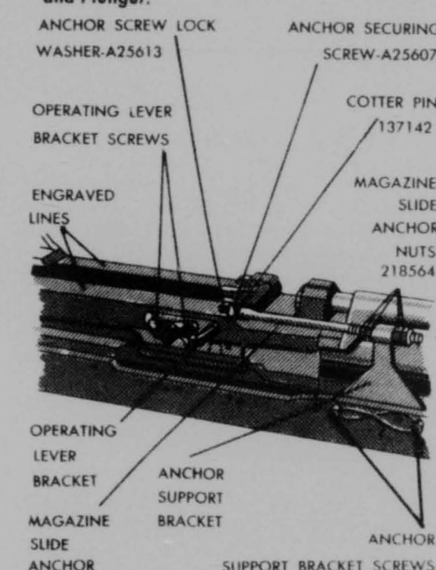


Figure 1—24. Adjustment of Magazine Slide and Installation of Operating Bracket.

The backplate and the two latch springs are removed.

The cotter pin is taken out of the magazine slide lever pin and the lever pin, lever, and latch removed.

The magazine slide is slipped to the rear and off the receiver.

The cotter pin is removed from the anchor securing screw, and the anchor screw lock washer is taken off.

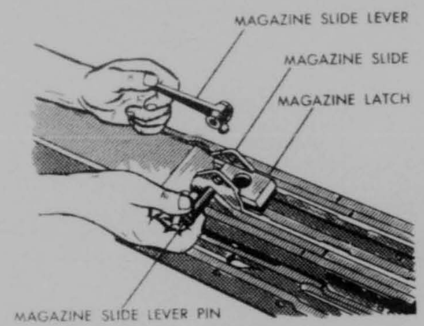


Figure 1—25. Assembly of Magazine Slide.

The anchor securing screw is removed and the magazine slide anchor withdrawn from the magazine slide. (Magazine slide parts are shown in Figure 1-10.)

Assembly (Figure 1-7)

The magazine slide anchor is fitted to the magazine slide. (The threaded end of the anchor should point away from front end of slide (Figure 1-10). The anchor should be on same side with anchor support bracket.)

The anchor securing screw is screwed in; the anchor screw lock washer is replaced, and secured with the cotter pin.

The magazine slide (anchor leading) is slipped on the gun.

The magazine latch is placed on the upper grooves in the rear of the magazine slide. (The sharp end of the latch should point toward the muzzle of gun so that the angle surface on the latch can be seen when looking down.)

The magazine slide lever is positioned on the magazine latch. (The ball on the lever should fit into the hole of the latch, the lever handle should point to the rear, and the holes in the magazine slide should align with the hole in the lever.) The lever pin is pushed in and secured with the cotter pin (Figure 1-25).

The two latch springs are seated in the rear of the latch.

The magazine slide backplate is placed flush against the latch springs and the two magazine slide backplate screws are inserted evenly. The screws are then lock-wired.

Figure 1—26. Positioning Breechblock Unlocking Tool in Gun.

The two ejector springs are seated in the rear of the ejector. The ejector is positioned in the two grooves of the magazine slide below the latch and slipped to the rear until the ejector stud protrudes through the hole in the backplate.

The fiber ejector stud washer is placed on the ejector stud, followed by the steel ejector stud nut washer. The ejector stud nut is then screwed on and the nut secured to the stud with a cotter pin.

The anchor front nuts are then replaced.

6. BREECHBLOCK GROUP

Removal and Installation

Removal of Breechblock. The rear buffer is removed. The two magazine slide anchor rear nuts are backed up all the way (Figure 1-26) and the magazine slide moved forward as far as it will go.

The breechblock unlocking tool is placed on the right side of breechblock in the receiver and the tool manipulated so that the projection on the arm of the tool engages the front face of the right breechblock slide, and the other arm of the tool is along the top of the breechblock with its end against the receiver.

The lever of the tool is pressed forward until the breechblock is unlocked.

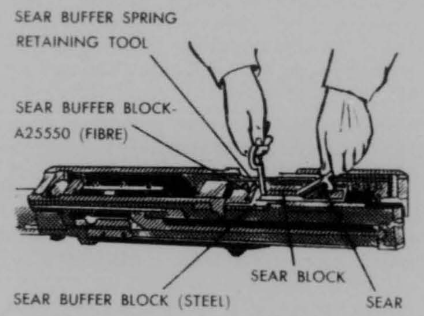


Figure 1—27. Removing Sear and Sear Block from Receiver.

The breechblock then is moved to the rear of the receiver. As soon as it starts to come out, the breechblock lock is grasped and held in the unlocked position. (Failure to do this may cause the breechblock to jam in the rear portion of the receiver.) The breechblock is pulled out of the receiver. (Care should be taken so as not to drop the breechblock lock.

Installation of Breechblock. The breechblock lock is attached to the breechblock by forcing the breechblock slides rearward and, at the same time, exerting pressure against the lock until it is in the unlocked position. The breechblock is held firmly in this position and pushed into the receiver as far as it will go so that the lock will not spring out of position.

The breechblock is then pushed home, the rear buffer replaced and the magazine slide adjusted.

Removal of Sear Mechanism. The cradle is removed from the gun. The twc mounting screw lock plates are straightened, the cradle mounting plate is unscrewed from the receiver.

The sear buffer retaining tool is inserted into the hole in the sear block. The tool is pushed through the sear block so that it fully engages the circumferential grooves on the sear buffer spring plungers (Figure 1-27).

The sear block and sear are lifted out of the receiver with the retaining tool in place. The steel and fiber sear buffer blocks are removed from the receiver.

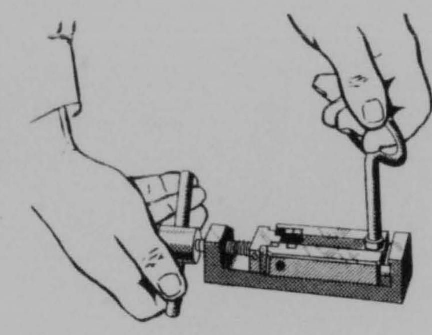


Figure 1—28. Disassembling Sear Block.

Installation of Sear Mechanism. The sear, with sear block, is replaced in the receiver. (The sear buffer spring retaining tool should not be removed.)

The sear buffer steel block is then replaced in the receiver adjacent to the sear block.

7. DISASSEMBLY AND ASSEMBLY

Disassembly of Breechblock

The breechblock lock, and the left and right inertia blocks (Figure 1-11) are removed.

The left breechblock slide is withdrawn in such manner as not to let the breechblock slide spring and guide fly out. The breechblock slide plate assembly is then withdrawn. The breechblock slide key should not be removed except for replacement.

The extractor is pressed against the contractor spring and the extractor pin drifted out. The extractor and extractor spring is withdrawn. The front end of the breechblock is lifted and the firing pin allowed to slide out through the rear. (The firing pin must not be dropped.)

Assembly of Breechblock

The firing pin is inserted in the bore of the breechblock, sliding it forward to a position

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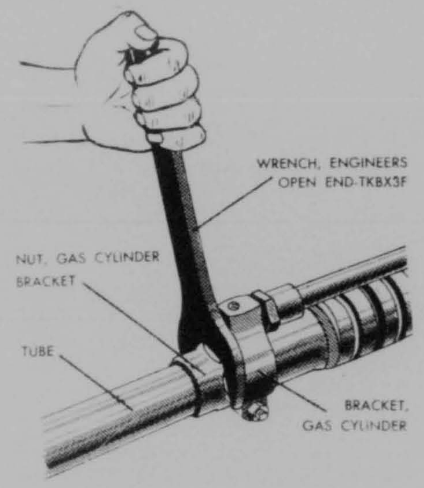

Figure 1–29. Removing Gas Cylinder Bracket Nut.

where the slot in the firing pin aligns with the recess of the breechblock slide key.

The extractor spring and extractor is installed and secured with the extractor pin.

The right-hand breechblock slide assembly is installed so that the slide key engages the slot in the firing pin. The left-hand breechblock slide is then put into place.

One breechblock slide spring is mounted on the guide. The rear end of the spring (and guide) is positioned in the hole of the breechblock pin, and the plunger and spring forced against the pin and sideways into the slide until the ball on the guide is in circular seat position in the slide. The second spring and guide are similarly installed.

The inertia blocks are then placed in position.

Disassembly of Sear Mechanism

The sear is detached from the sear block by withdrawing the sear pin.

The sear block is placed in the sear block assembling tool so that the radial bearing surface of the sear block contacts the jaw of the tool, while the plungers which protrude from the sear block engage the hook-shaped projection at the front of the tool (Figure 1-28). The sear buffer spring retaining tool should enter the hole in the sear block assembling tool.

The handle of the sear block assembling tool is turned sufficiently to take the tension off the sear buffer spring retaining tool. The retaining tool is removed and the handle of the tool is gradually turned to release the tension of the springs. The plungers and springs are removed. If the special sear block assembling tool is not available, an ordinary vise will serve. If the retaining tool is not available, a slightly tapered steel rod, which nearly fills the hole, may be used.

Parts of the sear mechanism are shown in Figure 1-12.

Assembly of Sear Mechanism

The sear buffer springs are inserted in their recesses in the sear block and the plungers replaced with their hollow ends against the springs.

The unit on the sear block assembling tool is replaced with the flanged side of the sear block up, and with the radial bearing surface against the jaw of the tool. The springs are compressed until the sear buffer spring retaining tool can be inserted to engage the grooves of the plungers.

The handle is loosened and the sear block removed with the retaining tool from the assembling tool.

The sear is attached to the block so that the forked end of the sear is on the same side as the flanged side of the sear block.

8. GAS CYLINDER SLEEVE GROUP

Disassembly

The cotter pin and lock washer are removed from the gas cylinder guide which is then unscrewed (Figure 1-13).

The gas cylinder sleeve spring is removed.

The locking wire from gas cylinder bracket plug and then the gas cylinder lock washer are removed. The gas cylinder bracket plug is then unscrewed.

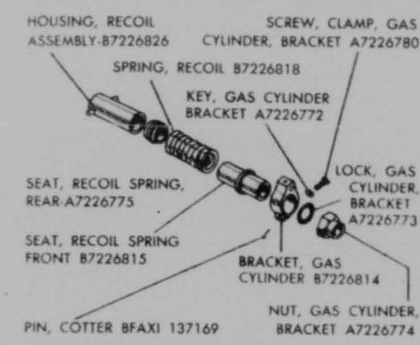

Figure 1—30. Parts of Recoil Group.

The gas cylinder lock plate is removed and the gas cylinder vent plug is unscrewed.

The gas cylinder is pushed to the rear and the gas cylinder removed with the sleeve.

The gas cylinder sleeve push rods are then withdrawn.

Assembly (Figure 1-13)

The gas cylinder sleeve push rods are inserted into their recesses in the receiver.

The gas cylinder is attached to the gas cylinder piston on the sleeve, the unit is positioned on the gun tube and slipped forward so that the gas cylinder fits in the opening in the gas cylinder bracket.

The gas cylinder vent plug is screwed in and the gas cylinder lock plate replaced.

The gas cylinder bracket plug is screwed in; the gas cylinder lock washer is replaced and secured with locking wire.

The gas cylinder sleeve spring is replaced.

The gas cylinder guide is screwed in, the lock washer is replaced and secured with the cotter pin.

9. RECOIL GROUP

Disassembly

The gas cylinder sleeve group and trunnion blocks are removed.

The cotter pin is extracted and the gas cylinder bracket clamp screw nut backed off several turns.

The tab of the gas cylinder bracket lock is straightened and the gas cylinder bracket nut is unscrewed (Figure 1-29). (It will be noted that the helical recoil spring is decompressed slowly as the nut is backed off.) The bracket nut should not be removed without first loosening the bracket clamp screw (Figure 1-30). (To do so would be dangerous, as the bracket would be thrown off with considerable force by the recoil spring.)

The screw, key, and nut are removed from the gas cylinder bracket.

The bracket, front recoil spring seat, recoil spring, rear recoil spring seat, and the recoil housing assembly are slipped from the tube.

Assembly

The recoil housing assembly, rear recoil spring seat, recoil spring and front recoil spring seat are installed over the tube in the order given.

The bore of the gas cylinder bracket and also its bearing surface on the tube are cleaned. The bracket on the tube is positioned with the side nearest the vent plug opening toward the muzzle of the gun.

The key is positioned in the slot at the bottom of the bracket and aligned with the keyway in the tube. The clamp screw and nut are installed and tightened lightly to hold clamp screw assembly in place.

A new bracket lock is installed with the tang located in keyway of the tube.

The front spring is positioned to have the flat directly on top (Figure 1-14). (This allows clearance for the gas cylinder hex head.)

The bracket nut is installed and tightened until the gas cylinder bracket is seated against the tube shoulder. The nut must be drawn up snug and secured by bending an edge of the bracket lock down over one flat of the nut.

Trunnions of the ring spring housing are positioned in a horizontal position. The nut is tightened on the clamp screw and the cotter pin installed.

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SECTION III—CYCLE OF OPERATION

1. OPERATION UNDER NORMAL CONDITIONS

Hand Loading of Belts for Feed Mechanism AN-M2

General. Belts for the 20-mm feed mechanism AN-M2 must be made up of 20-mm metallic belt links M7 or M8 only. No special end link is required.

All links must be inspected for rust, dirt, or deformation. All links are dipped in preservative lubricating oil (special) and the excess oil drained off just before using. A clean cloth is dipped in the special oil and wrung out; this is used to oil the cartridge cases, avoiding the joint where the case is crimped to the projectile.

For right-hand feed. The links are laid along a belting board with their open sides up, single loops to the right, and single loops positioned between the double loops (Figure 1-31).

The rounds are inserted into the loops and pushed forward.

The position of the cartridges relative to the links is checked. (The distance from the base of the cartridge case to the rear edge of the double loop should be 2 9/32 inches plus or minus 1/16 inch.)

The belt is tested for flexibility by lifting the left-end loop and drawing it along the top of the belt to the right. Any faulty link will cause the belt to kink instead of folding over smoothly. Any link which does not hinge freely must be replaced by another and the test repeated.

The above test is repeated, starting with the right-end loop and drawing it to the left. If a stiff link is found, it must be replaced by another and both right-end and left-end tests repeated.

The belt is tested for oversize links by suspending it from one end and twisting the lowest link until resistance is felt. If the belt breaks, the faulty link must be replaced by another and the tests repeated.

For left-hand feed. The procedure is the same as directed for right-hand feed but the links are placed on the belting board with their single loops to the left (Figure 1-32).

Joining of belts. The round is removed from the last double loop of one of the belts.

The empty single loop of the second belt is joined to the empty double loop of the first belt by inserting a round.

The position of the newly inserted round and the flexibility of the newly formed belt is then checked.

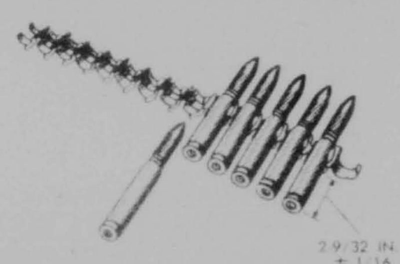


Figure 1—31. Hand Loading of 20-mm Links M8 for 20-mm Feed Mechanism AN-M2 (Right-Hand).

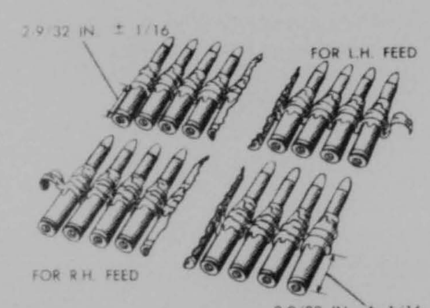


Figure 1—32. Loaded Belts (M8 Links) for 20-mm Feed Mechanism AN-M2 (Right and Left-Hand).

The position of the cartridges relative to the links is checked. (The distance from the base of the cartridge case to the rear edge of the double loop must be 2 5/16 inches plus or minus 1/16 inch.)

Note: The leading double loop must have a round; the single closed end loop must be empty.

The belt is then tested for flexibility and for oversize links.

Hand Loading of Belts for Feed Mechanism M3

General. Belts for the 20-mm feed mechanism M3 can be made up of 20-mm metallic belt links M3, M3A1, M7, or M8. A special end link is employed as the trailing link of the belt. (The use of different types of links in the same belt is prohibited.)

The links and rounds are then inspected and oiled.

For right-hand feed. The links are laid along a belting board with their open sides up, double loops to the right, and single loops positioned between the double loops. The last link on the left end must be of the special type with the closed loop (Figure 1-33).

The rounds are inserted into the loops and pushed forward.

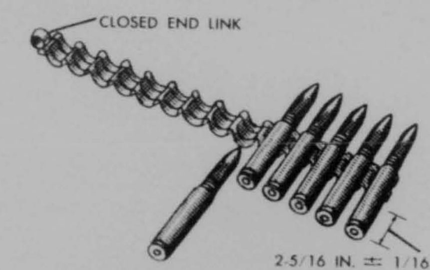


Figure 1—33. Loading 20-mm Belt Links M3 for 20-mm Feed Mechanism M3 (Right-Hand).

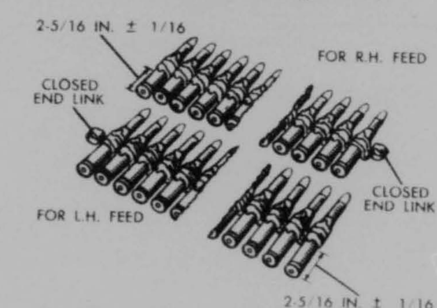


Figure 1—34. Loaded Belts (M7 Links) for 20-mm Feed Mechanism M3 (Right-Hand and Left-Hand).

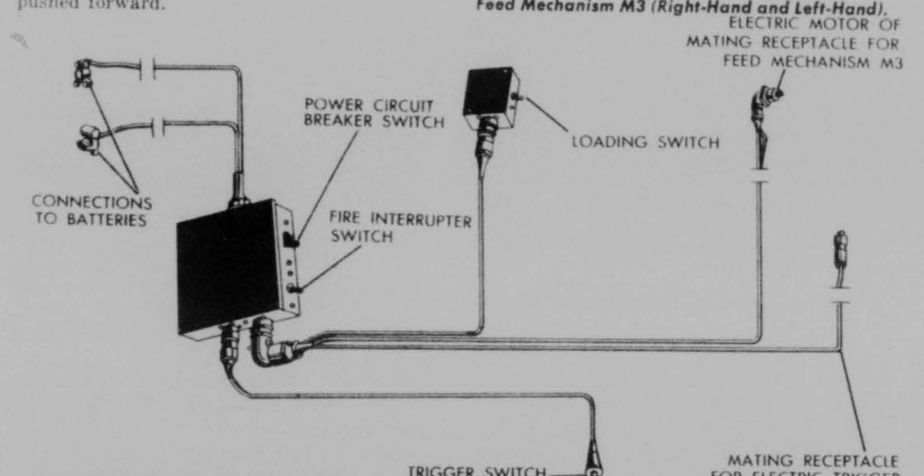
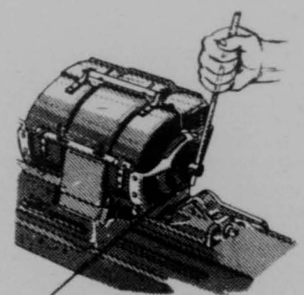


Figure 1—35. Controls for Firing of Gun Equipped with 20-mm Feed Mechanism M3.



DRIVE SPRING RELEASE SHAFT PUSH SHAFT IN ABOUT 3/16 INCHES WHEN UNWINDING DRIVE SPRING

Figure 1—36. Unloading the Gun (Using 20-mm Feed Mechanism AN-M2).

For left-hand feed. Procedure is the same as directed for right-hand feed, but the links with double loops are placed to the left, and the special end link on the right (Figures 1-33 and 1-34).

Joining of belts. The round and the special end link are removed from the end of one belt, and the round from the first double loop of the second belt.

The two belts are joined by means of a round and the position checked.

If the new belt does not have a special end link, the special end link is joined to the new belt by means of a round. Position of round is then checked.

2. FIRING OF GUN

Using 20-mm Feed Mechanism AN-M2

The firing switch is closed to fire the gun. To cease firing, the firing switch is released.

Using 20-mm Feed Mechanism M3

The fire interrupter switch is moved to "fire" position and the trigger switch is closed (Figure 1-35). To cease firing, the firing switch is released and the fire interrupter switch moved to the "safe" position.

Correction of Stoppages in Combat Firing. The design of the gun and its location outside the reach of the gunner usually make it impossible to remedy stoppages during combat firing.

When a stoppage occurs during combat firing, the gun should be recharged immediately. If the gun cannot be recharged, no corrective action is possible.

3. UNLOADING GUN

Using 20-mm Feed Mechanism AN-M2

The selector switch must be in the "off" position.

If the belt of ammunition has been completely expended, the feed and link chutes are disconnected from the feed mechanism, the magazine slide cover is raised, and the mechanism lifted off the gun.

If the belt of ammunition has not been completely expended, the drive spring release shaft is pushed in about $\frac{3}{16}$ inch and, at the same time, the shaft is turned for about three-quarters of a turn in the direction opposite to that of feeding (Figure 1-36). This will completely unwind the drive spring. The belt is pulled from the feed mechanism. The feed and link chutes are disconnected from the feed mechanism, the magazine slide lever is raised, and the mechanism lifted off the gun.

Note: If there is a round in the mouth of the magazine, it is removed by being pushed forward carefully.

Using 20-mm Feed Mechanism M3

The fire interrupter switch is moved to the "safe" position and the power circuit breaker switch to the "off" position (Figure 1-35). The electrical receptacles are disconnected at the feed mechanism.

The feed and link chutes are disconnected from the feed mechanism, the slide latch lever is rotated upward, the rear end of mechanism is disengaged from the feed slide, and the mechanism lifted off the gun.

The cover locking pins are pulled out as far as they will go, the stripper cover is raised, and the belt removed.

Note: If there is a round in the mouth of the magazine, it must be removed by pushing it forward carefully.

4. OPERATION UNDER UNUSUAL CONDITIONS

General

Because of the different climatic and temperature conditions in which this materiel may be expected to operate, special instructions are given in this section. These instructions must be carefully observed.

5. EXTREMELY HIGH TEMPERATURES

Lubrication

The gun is lubricated as directed in section IV. Extremely high temperatures require more frequent lubrication.

Inspection and Care

Materiel should be inspected frequently when being operated in hot, moist areas. Items which may deteriorate from mildew, or which may be attacked by insects or vermin should be aired or dried frequently.

Ammunition should be kept out of the direct rays of the sun. Moisture-resistant seals should not be broken until ammunition is to be used.

6. SUBZERO TEMPERATURES

In temperatures which are below the freezing point, it is essential that all moving parts be kept absolutely free of moisture. Excess oil on the working parts will solidify to such an extent as to cause sluggish operation or complete failure. Extreme cleanliness is essential; oil must be applied sparingly.

When a gun is brought into a heated shop, condensation will occur on the metal surfaces. After the gun has reached shop temperature, all parts must be wiped dry and recoated with oil to prevent rusting.

In applying oil to the bore after cleaning, care must be taken to work the oil in well so that it will reach all surfaces of the lands and grooves.

The breechblock parts are cleaned with rifle-bore cleaner; oil is applied by wiping the rubbing surfaces with a clean cloth which has been wet with the oil and wrung out.

When materiel is protected by canvas or other type of cover, moisture will form on the metal surfaces. To prevent rusting, the cover must be removed at least once each week, and all surfaces thoroughly dried. Where necessary, parts should be reoiled.

7. EXCESSIVELY MOIST OR SALTY ATMOSPHERE

When the materiel is active, exposed metal surfaces, such as the gun, breechblock, and cradle surfaces, should be oiled more frequently, as water will emulsify with oil and destroy its rust-preventive qualities. Parts should be inspected frequently for corrosion.

Preservative lubricating oil (medium) is used in lieu of lubricating oil (special).

The bore of the tube and the breechblock should be kept heavily oiled and should be inspected frequently for rust. The bore should be wiped clean before flight when firing is contemplated.

8. EXCESSIVELY SANDY OR DUSTY CONDITIONS

When the gun is active in dusty or sandy areas, the gun must be inspected and wiped clean every day, or oftener if necessary. Groups should be removed to facilitate thorough cleaning.

Lubrication should be kept to a minimum as oil collects dust which will act as an abrasive and may foul the bore and chamber. Preservative lubricating oil (special) should be applied lightly to working parts.

The breech and muzzle should be covered when practicable.

9. CYCLIC FUNCTIONING OF WEAPON

General

The cyclic functioning of the weapon as a whole, from the firing of one round to the next, is described in the following paragraphs. For purposes of explanation, the

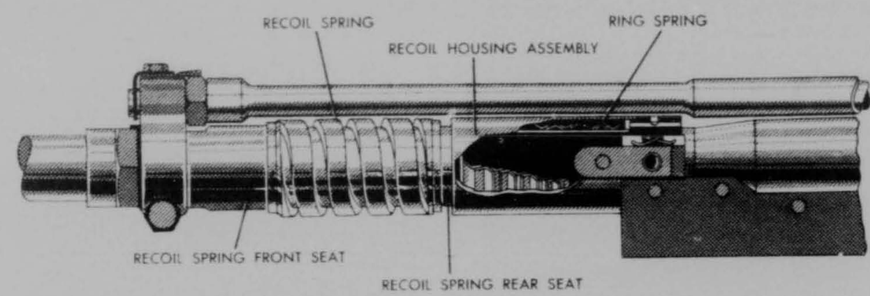


Figure 1—37. Action of Recoil Spring and Ring Spring.

cyclic functioning is divided into the following actions:

- Recoil action.
- Breechblock unblocking action.
- Extraction and ejection.
- Rear buffer and driving spring action.
- Cocking action.
- Feeding and chambering.
- Breechblock locking action.
- Firing action.

Recoil Action (Figure 1-37)

When the round is fired, the pressure of the propellent gases in the tube forces the gun to recoil to the rear for about one inch. As the gun recoils, the recoil spring front seat and the gun tube move to the rear and compress the recoil spring. Since the compression of the ring spring in the recoil housing assembly is greater than the final force of the recoil spring, the recoil spring alone, during this phase of the recoil, will offer resistance to the rearward movement of the gun. This action will continue until the gun has recoiled for about [illegible] inch. At this point, the rear end of the recoil-spring front seat contacts the front end of the recoil spring rear seat, thus stopping the compression of the recoil spring. While the recoil spring rear seat begins to compress the ring spring of the recoil housing assembly which absorbs the remaining shock of recoil, the recoil spring begins to recover. The recovery of the recoil spring returns the gun into battery.

The ring spring of the recoil housing assembly will act as a counterrecoil buffer if the gun should travel past its battery position.

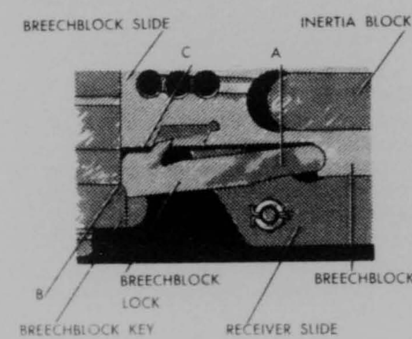


Figure 1—38. Breechblock Lock in Locked Position at Moment of Firing.

The ring springs will be compressed in the same manner as during recoil movement of the gun, but the action of the parts will be reversed.

Breechblock Unlocking Action

The breech is unblocked by the action of the gas cylinder sleeve group. At the moment of firing, the breechblock is held in its forward position by the action of the breechblock lock. The lock engages the breechblock at point A (Figure 1-38) and bears against surface B of the breechblock key. The breechblock slide engages the lock at point C, thus preventing the lock from being forced upward prematurely.

As the round is fired, the projectile is driven forward in the tube, passing the gas port (Figure 1-39). A portion of the expand-

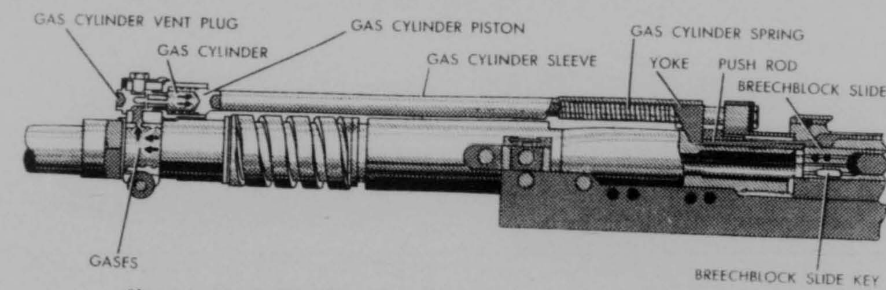


Figure 1—39. Action of Gas Cylinder Sleeve Group for Unlocking the Breech.

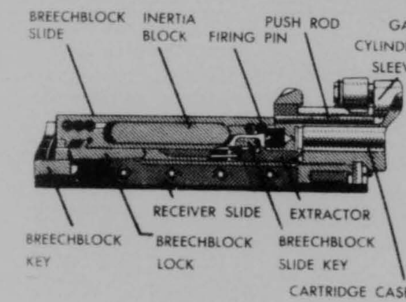


Figure 1—40. Unlocking of Breechblock and Retraction of Firing Pin.

ing gases enters the gas port and passes through the gas cylinder vent plug into the gas cylinder (Figure 1-39). As the gas expands against the gas cylinder piston, it forces the piston and the gas cylinder sleeve (integral with it) to the rear, compressing the gas cylinder spring.

As the sleeve is forced to the rear, the yoke on the sleeve contacts the two push rods which, in turn, move the breechblock slides rearward to unlock the breechblock (Figure 1-40). The slides are connected to the slide key which engages a slot in the bottom of the firing pin. As the slides are forced rearward by the push rods, the key retracts the firing pin. The moment the breechblock is unlocked, it is forced to the rear by blowback action with a resultant drop of gas pressure in the tube. As the gas pressure drops, the gas cylinder sleeve spring expands, returning the sleeve and piston to the original position.

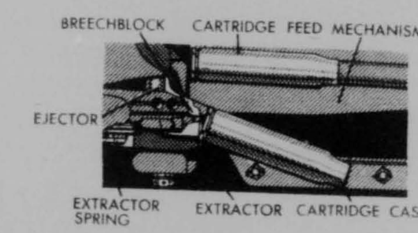


Figure 1—41. Ejection of Cartridge Case.

Extraction and Ejection

When the breechblock assembly is forced to the rear, the empty cartridge case, which has been forcing the bolt back by blowback action, is contacted on the upper edge by the two prongs of the ejector (Figure 1-41), causing the cartridge case to pivot about and forcing down the forward end of the extractor. The cartridge case leaves the lip of the extractor and moves through an opening in the bottom of the receiver, completing the ejection of the empty cartridge case. When the cartridge case frees itself from the extractor, the extractor is returned to its normal position by the action of the extractor spring.

Rear Buffer and Driving Spring Action

As the breechblock is driven rearward, it compresses the driving spring. When the breechblock nears the end of its rearward movement, it strikes the rear buffer washer

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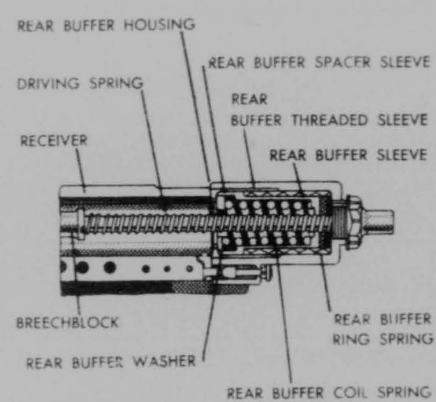


Figure 1—42. Rear Buffer Cross Section.

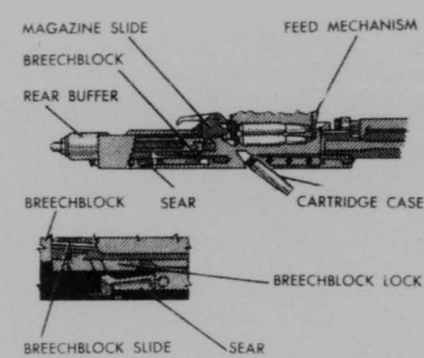
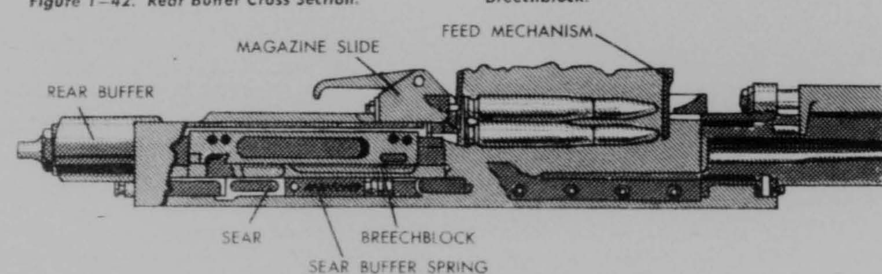


Figure 1—43. Action of Sear During Recoil of Breechblock.



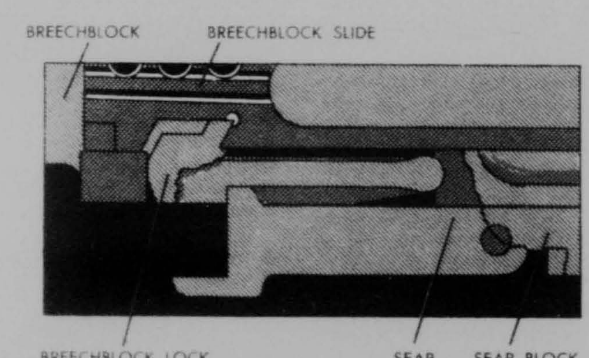


Figure 1—44. Engagement of Sear and Breechblock During Counterrecoil of Breechblock.

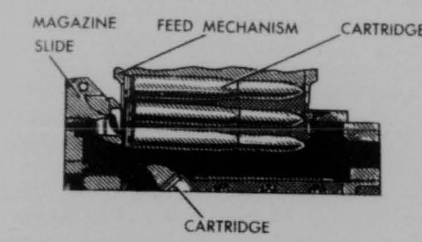


Figure 1—45. New Round Being Forced Downward Into Mouth of Feed Mechanism.

which transmits the shock of recoil to the buffer springs which absorb the remaining force of recoil and bring the breechblock to a stop (Figure 1-42). As the breechblock comes to a stop, the inertia blocks continue to move rearward in their slots in the breechblock slide until they reach the end of the slots. By this time the breechblock has started forward again, and the inertia blocks remain in a rearward position with respect to the breechblock slides during the forward motion of the breechblock. The rear buffer springs and the driving spring expand, forcing the breechblock forward.

Cocking Action

As the breechblock is forced to the rear by blowback, it passes over and depresses the sear (Figure 1-43), then, when the breechblock starts forward, and the sear is released, the sear will engage the breechblock lock and hold the breechblock in the rear position (Figure 1-44). The shock produced when the sear and breechblock engage is absorbed by the sear buffer springs and the sear buffer plates. If the sear is held down by actuating the trigger, the breechblock will move forward into the locked position under the force of the driving spring.

Feeding and Chambering
(Figures 1-45 and 1-46)

When the recoiling breechblock is sufficiently far to the rear to clear the feed mechanism, a new round is forced downward into the mouth of the feed mechanism. As the breechblock is forced forward by the driving

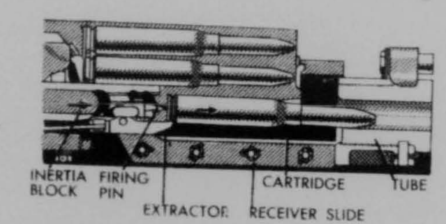


Figure 1—46. Ramming of a Round.

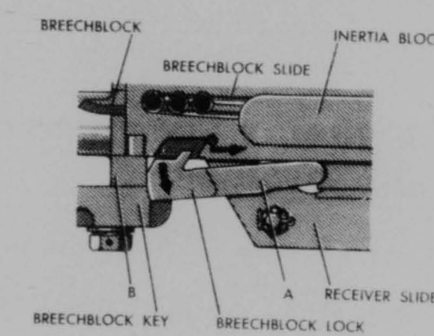


Figure 1—47. Breechblock in Locked Position.

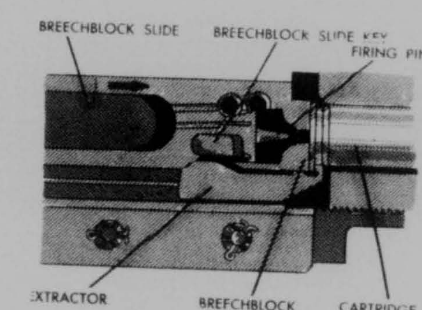


Figure 1—48. Firing Pin Moving to Fire Round.

spring, it engages the new cartridge which has been positioned in the mouth of the feed mechanism. As the cartridge is forced forward, it drops into the recess in the bolt where it is gripped by the lip of the extractor as it enters the chamber.

Breechblock Locking Action

As the breechblock reaches the end of its forward motion (Figure 1-47), it seats against the end of the tube, closing the chamber. The momentum of the slides and the action of the slide springs cause the slides to continue to move forward, releasing the breechblock lock. At the same time, projecting cams of the lock (A, Figure 1-47) are engaged by cam surfaces on the receiver slides which, together with the action of the cams on the bevel of the lock, cam the lock downward. The lock seats against the breechblock key and is locked in its downward position by the lower surface of the breechblock slides which move over the rear end of the lock.

Firing Action (Figure 1-48)

As the slides approach the end of their forward motion, the firing pin is carried forward by the slide key and the driving spring to fire the round. When the slides have reached the end of their forward motion, the inertia blocks continue to move forward for a short distance, striking against the forward end of the slot, thereby counteracting any rebound tendency of the slides or pin.

SECTION IV—INSPECTION, MAINTENANCE AND CLEANING

SPRING SPECIFICATIONS

	Free length (inches)	Allowable free length (inches)
Gun:		
Breechblock slide spring	2.87	2.58
Driving spring	26.5	23.5
Ejector spring	1.89	1.70
Gas cylinder sleeve spring	5.60	5.04
Magazine latch spring	2.83	2.54
Sear buffer spring	1.89	1.70
Feed mechanism M3:		
Operating lever springs	1.218	1.09
Round retaining finger spring	1.187	1.06
Pneumatic charger M4:		
Piston return spring	26	23.4
Head return spring	8.75	7.87
Manual charger M6:		
Slide return spring	14	12
Spring (for latch locking ball)	.406	.366
Hydraulic charger M7:		
Piston return inner spring	22.5	20
Piston return outer spring	23	20.5
Hydraulic charger M5:		
Piston return spring	22	20
Electric trigger AN-M1A1:		
Sear return spring	.92	.83
Electric trigger AN-M4:		
Solenoid spring	1.156	1.04

Figure 1—49. Spring Specifications.

1. OPERATIONAL INSPECTION

The following general points should be carefully noted in the inspection of the materiel:

All operating mechanisms are inspected for ease of operation, backlash and sufficient lubrication.

At least every six months a check-up should be made to insure that all modifications have been applied. (A list of current modification work orders is published in FM 21-6, the final edition of which is dated 1 January 1949. Future listings and index of DA publications will be published in the 310-20 series of special regulations. If a modification has not been applied, the local ordnance officer must be notified promptly. No alteration or modification which will affect the moving parts should be made by the using personnel, except as authorized by the Ordnance Department.)

Safety features are inspected to determine proper functioning. Lettering on name plates and direction plates of feed mechanisms should be checked to determine that they are legible.

Weapon covers are inspected.

ORGANIZATIONAL MAINTENANCE SCHEDULE

A. DAILY.

Point	Preventive maintenance
Bore	Check for rust and/or fouling.
Gun	Check for rust and cleanliness.
Feed mechanism	Check for rust and cleanliness.
Chargers	Check for rust and cleanliness.

B. BEFORE FIRING.

Point	Preventive maintenance
Barrel and receiver	Clean and oil
Feed mechanism AN-M2.	Lubricate
Feed mechanism M3.	Lubricate
Magazine slide (feed mechanism AN-M2).	Dynamic torque test. Check alinement of engraved lines on slide and receiver. Check operation of latch.
Feed mechanism	Clean and lubricate. Inspect
Trigger	Inspect and check operation.
Heater	Clean and check operation.

Point	Preventive maintenance
Feed slide (feed mechanism M3).	Check alinement of engraved lines on slide and receiver.
Magazine slide anchors.	Check for tightness of nuts.
Trigger	Check for operation
Charger	Check for operation
	Lubricate (manual charger M6).
Heater	Check for operation

C. AFTER FIRING.

Point	Preventive maintenance
Breechblock	Remove, disassemble, clean, and oil.
Bore	Clean.
Gas cylinder and sleeve group.	Clean and inspect
Gun in general	Inspect for broken and loose parts, proper adjustments, etc.
Charger	Check for operation.
Flash hider	Check for tightness.

Figure 1—50. Organizational Maintenance Schedule.

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Accessories, tools, spare parts, and equipment are inspected for completeness and serviceability.

The weapon should be checked for damage or deterioration of paint.

Whenever the items are disassembled, all springs listed below are inspected for free length, kinds, and breaks. Springs which are broken or kinked, or whose free length is less than the allowable, are replaced. (See Figure 1-49.)

2. COMMON PREVENTIVE MAINTENANCE PROCEDURES

The general preventive maintenance outlined below must be observed in addition to that referred to in the schedules listed in Figure 1-50.

Assemblies containing ring springs must not be dipped of washed in dry-cleaning solvent. (These units are lubricated by the manufacturer and if this special lubricant is diluted with cleaning solvent, early failure of the unit will result.)

Rust, dirt, grit, gummed oil, and water cause rapid deterioration of internal mechanism and outer unpainted surfaces. Particular care should be taken to keep all bearing and sliding surfaces clean and properly lubricated. All traces of rust should be removed with crocus cloth.

Loose parts are tightened; broken parts must be replaced; lock washers, safety wire, cotter pins, and other locking devices should be properly applied.

Most of the parts on this weapon are finished by the Parco-Lubrite process. The resistance of this type of finish to corrosion is greatly enhanced by the application of a light coat of oil. Accordingly, a light coat of oil is maintained on all "Parto-Lubrited" parts.

Only those tools which are provided should be used, and they must fit snugly on parts. Tools which do not fit will fail or cause damage to parts. Accessories, tools, and spare parts must be inspected for serviceability. Missing or damaged items are replaced or turned in for repair.

3. ORGANIZATIONAL MAINTENANCE SERVICE

The items or points to be inspected and serviced at scheduled times are listed in Figure 1-50.

4. GENERAL ORDNANCE MAINTENANCE

Inspection and Testing

Every gun received by ordnance maintenance personnel for rebuilding must be thoroughly and completely inspected, put into the best condition possible with the allowable time, materials and technical circumstances. They are then returned to the using arm ready for immediate use.

The general appearance should be noted, a check made for rust formation, missing bolts, nuts, locking devices, and wires. A visual inspection is made for cracks, breaks, or deformed parts. The cradle mounting plate is checked by lifting the gun while it is still in the cradle. Anchor support brackets are inspected for proper tension of screws.

The bolt is cocked and the electric trigger connected to a 24-volt direct current power supply. The sear action should be instantaneous. If the sear is not tripped, and it is known that the solenoid was energized, the solenoid is removed and the amount of effort required to trip the sear is determined. (This should not require more than fifty pounds.) The locking surfaces of both the sear and the breechblock are inspected for scores, mutilation, or a defective sear plunger and spring which would cause excessive firing effort.

With the bolt and rear buffer removed, the bore is cleaned and the rifling examined. (Excessive wear, serious erosion, or deformation of the tube would be cause for its rejection.)

The chamber is examined for scores and burrs. Failure to extract and eject the cartridge properly can be caused by a scored chamber or a faulty extractor. The average life of a tube under favorable conditions is approximately 5,000 to 6,000 rounds. With the bolt retracted, the breechblock locking key and receiver slides are inspected. The key

THREAD SIZES OF PARTS

Item	Ordnance No.	Pitch
Anchor, magazine slide	B7226812	5/16-24NF-2.
Bracket, gas cylinder	B7226814	10-mm—1.5-mm Int. Form.
Bracket, mounting	C7226810	3/8-16NC-2.
Cylinder, gas	B163311	14-mm—1.5-mm Int. Form.
Guide, gas cylinder	A25582	20-mm—1.5-mm Int. Form.
Head, driving spring guide	B7231159	
Outer end		5/8-18NF-2.
Inner end		25-mm—1.5-mm Int. Form.
Key, breechblock locking	B7226047	3/8-24NF-3.
Plug, gas cylinder bracket	B163320	10-mm—1.5-mm Int. Form.
Plug, gas cylinder vent	B7229626	14-mm—1.5-mm Int. Form.
Receiver	D7226842	
Hole to receive tube		52-mm—2.5-mm Int. Form.
Hole for gas cylinder sleeve guide		20-mm—1.5-mm Int. Form.
Holes for securing M6 manual charger		0.190 (No. 10)-32NF-2.
Holes to attach M1 heater		0.190 (No. 10)-32NF-3.
Holes for attaching operating lever bracket of AN-M2 feed mechanism		5/16-24NF-2.
Holes to attach electric trigger		7-mm—1-mm Int. Form.
Slide, magazine	C70497	7-mm—1-mm Int. Form.

Figure 1—51. Thread Sizes of Parts.

must not be loose or show signs of any mutilation. Excessive wear on the key will result in more than the allowable headspace between the cartridge case and the face of the breechblock. Loose or scored receiver slides will cause binding of the bolt action and reduce the firing speed of the gun.

With the breechblock in its forward position, a feeler gauge is used to check the clearance between the push rods and gas cylinder sleeve yoke. The clearance should not be more than 0.042 inch and should check the same on both sides within 0.003 inch. If greater difference is found, a sprung yoke on the gas cylinder sleeve, mushroomed push rods, or defective breechblock slides are indicated. These conditions must be remedied, or a binding action may develop in the bolt. The gas cylinder sleeve is inspected for straightness. A bent sleeve will cause an apparent difference in the length of the push rods.

The slide is checked to determine ease of operation. The ejector is inspected for wear. (Worn or damaged ejectors will cause rounds to position improperly in the feed mouth. Cartridge cases will not eject properly if the ejector is loose or out of position in the magazine slide.) The action of the magazine slide latch and lever assembly is tested to see that it operates smoothly with a positive action.

The cradle must be examined for damaged or loose brackets. (Any play in screws or rivets in this member will soon develop into a serious condition.) Trunnion blocks must be secure on the mounting brackets. (Any play between blocks and the trunnions will necessitate replacement of the worn part.)

The adapter assembly is inspected visually. Dry-cleaning solvent or vapor degreasing methods must not be used on the gun adapter. A check is made for broken recoil springs or damaged parts. The condition of the trunnion on either side of the recoil housing is inspected.

If the gun is equipped with the feed mechanism M3, the loading switch is closed and the action of the feed mechanism observed. The stripper cover is raised and the feed wheels, link stripper and loading levers inspected for wear or damage. The tension of the loading lever springs is checked. The feed mechanism AN-M2 should be inspected in a similar manner, except that it cannot be operated without having rounds in place. The condition of the

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stripper cams and link chute is inspected. The tightness of screws holding the operating lever brackets to the cradle is checked and the operating link assembly examined for missing cotter pins or loose nuts.

The current supply is turned on and the heating elements tested. The wiring connections and terminals are inspected.

The charger is tested to determine if all connections are tight. (Loose connections will prevent chargers from operating correctly.)

A report should be made to the responsible officer concerning any pertinent carelessness or negligence in the preventive maintenance procedures and safety precautions. This report should be accompanied by recommendations for correcting the unsatisfactory conditions.

5. COMMON ORDNANCE MAINTENANCE PROCEDURES

General

The general procedures given below should be followed during repair and rebuild operations:

Subassemblies and groups are assembled before mounting them on the gun. As a part of all assembly and mounting operations, the thread, slide surfaces, and mating parts are cleaned and lubricated.

When assembling the gun, new cotter pins, locking plates, and locking wire are used, and tied or fastened in an approved manner. In checking for cracks, it is recommended that magnaflux equipment be employed if available.

All burrs are removed from sliding surfaces with a fine oil stone and the surfaces polished with crocus cloth. All abrasive is washed off with dry-cleaning solvent.

All burrs are removed from threads by chasing with the proper size of taps or dies if available. (Most threads on this gun are metric sizes.) Following is a list of thread sizes of parts which may require cleaning: (See Figure 1-51).

Function Testing

The gun is placed in a suitable fixture, fastened securely, and properly lubricated. The bolt, when cocked, should retract properly with the charger mounted in either the right- or left-hand position. The electric trigger is connected to a suitable source of 24-volt direct current power to test the action of the breechblock and sear. The bolt should go forward to battery position and lock. Any malfunction observed would be due to improperly fitted breechblock components or a faulty electric trigger; therefore, the "dry-firing" test is of utmost importance. The position of the magazine slide on the receiver is checked by observing scribe lines. The anchor rod is adjusted so as to have the center pair of scribed lines coincide. This adjustment is very important. Be sure adjusting nuts and lock nuts on the anchor are tightly secured after alignment is attained.

A feed mechanism is then installed on the gun. If the AN-M2 type is to be used, a belt is made up of dummy rounds. The feed chute adapter and ammunition chute are installed with the feed mechanism. The belt is inserted into the feed mouth with an empty, single-loop leading. The feed mechanism spring is wound the full amount by turning the main drive shaft from the front end and using a wrench on the hex end. This action draws the rounds down into the feed pawls and stops the first round in contact with the top of the bolt. The bolt is operated several times with a charger to test the action of the stripper cams, cartridge pawls, and positioning of rounds in the feed mouth. During this operation sufficient tension must be kept on the feed spring to stimulate actual gun operation. The action of ejector and extractor at this point should be noted.

Feed mechanism M3 is installed on the gun, a belt is made up of dummy rounds. The stripper cover is lifted and a belt of rounds started into the feed wheel. The stripper cover is closed and secured with the pins. The feed mechanism motor is connected to a 24-volt direct current power supply and the bolt operated with a charger to test the stripping and feeding action.

Note: Many malfunctions and jams of the gun and feed mechanism can be caused by faulty or misformed links.

Function Firing

In order to function-fire this weapon a sufficiently sturdy stand must be available to mount the gun. An opening must be situated within the top of the stand, large enough to permit empty cartridges to be ejected. The cradle is fastened securely to this stand in four places. The gun and stand is positioned so as to have projectiles hit in a pit or bank. The bore and chamber are cleaned and all assemblies are checked to see that they are properly adjusted and secured.

When function-firing a gun equipped with a feed mechanism AN-M2, a belt is made up of 25 or 30 M1 ball or T24 practice cartridges. By hanging the belt of approximately thirty rounds from the feed mouth, a suitable drag will be developed which will determine the condition of the driving mechanism spring assembly until the clutch slips. The end of the belt is inserted into the feed mouth and the driving mechanism assembly wound until the clutch slips. The feed operating lever is positioned in the bracket on the receiver and a check made to see that the latch is holding the lever in place. The gun is charged and when the charging lug has returned to the forward position, a short burst is fired to see that the gun recoils properly, ejects cartridges properly, and strips links without jamming. A burst of ten or fifteen rounds is fired to test for any similar malfunction. The rate of fire should not be below 650 rounds per minute. The remaining ammunition is fired in short bursts to test the driving mechanism winding assembly. In case of a jam, no attempt should be made to remove the feed mechanism without unwinding the main drive shaft spring.

When function-firing a gun equipped with a feed mechanism M3, a belt is made up of twenty-five or thirty M1 ball or T24 practice cartridges. Alignment marks on receiver and magazine slide should be rechecked. The stripper cover is raised, the first round is inserted between the feed-wheel fingers, the cover is closed and secured with the locking pins. The bolt should be in a forward position. The feed motor is connected to an electrical power source to feed the ammunition belt into the mechanism until the first round rests on top of the breechblock. The bolt is drawn back with the charger and sufficient time is allowed for the charging lug to return to its free position. A few short bursts are fired to test the trigger action and recoil actions, noting particularly whether links and cartridge cases drop free of the gun. A burst of ten or fifteen rounds is fired while watching the feed mechanism closely to determine any malfunction or slipping. If lag occurs, feed wheel clutch tension must be checked and tightened if found lower than 180 inch-pounds. Firing is continued to exhaust all rounds in the feed mechanism. The rear buffer should be checked carefully while function-firing tests are in progress. The buffer housing will heat up if the springs are broken. The inside of the buffer housing should be checked for pieces of loose metal which indicate broken springs or sleeves.

In the event a "dud" is encountered, it is extracted from the gun with the charger and the primer is examined. Light-struck primers denote a faulty firing pin, a broken or weak driving spring, or a fouled breechblock due to burnt powder or metal chips being built up inside the firing-pin hole. If the indentation in the primer appears deep enough, the round can be considered faulty.

6. CLEANING METHODS

Cleaning

Unless otherwise specified, rifle-bore cleaner should be used to clean or wash all metal parts, whenever partial or total disassembly is undertaken, or when renewing the protective lubricant film on exposed metal surfaces. The use of gasoline is prohibited.

Care must be taken when cleaning internal mechanisms to insure complete removal of all residue or sediment. Necessary wiping should be done with a piece of firm, lintless cloth. Dirt or other foreign matter should not be allowed to get into the lubricant and lubricating openings.

Lubrication

Lubricant should be applied while the parts are being operated by hand to insure proper distribution of lubricant to all moving parts.

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LUBRICATION INSTRUCTION

Feed Mechanism AN-M2----

a. Weekly and before firing, clean all accessible parts with a dry cleaning solvent and then wipe with a cloth dampened with preservative lubricating oil (special). If disassembly is undertaken, clean and oil all disassembly parts before assembling.

b. Lubricate the following with a drop of oil:
(1) Front holding cam.
(2) Rear holding cam.
(3) Cartridge control pawl.
(4) Operating crank bracket.
(5) Operating lever.
(6) Joints of link assemblies.
(7) Clutch driven hubs.

Feed mechanism, M3

a. Weekly and before firing clean all accessible parts with dry-cleaning solvent and then wipe with a cloth dampened with preservative lubricating oil (special). If disassembly is undertaken, clean and oil all dissasembied parts before assembling.

b. Lubricate the following with a drop of oil:
(1) Bearing faces of loading levers.
(2) Bearings of operating lever shaft.
(3) Pivotal connection between loading and operating levers.
(4) Bearings of the retaining finger fulcrum.
(5) Bearings of the slide latch.
(6) Oil cup on gear box (3 drops of oil).
(7) Pins of cartridge control pawl and cartridge holding dog.
(8) Balls and sockets of links.
(9) Fronts and rear bearings.
(10) Pivots of cartridge holding cams.

Pneumatic charger, M4 ----

a. Maintenance of the 20mm pneumatic charger M4 consists chiefly of replacement of worn or broken parts and cleaning and oiling daily and after firing.

Hydraulic charger, M7 ----

a. Maintenance of the charger involves mostly the replacement of worn or damaged parts and cleaning and oiling daily and after firing.

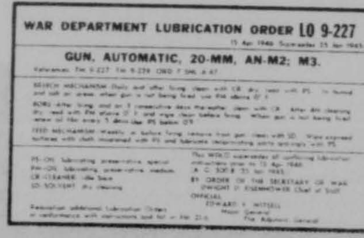
Hydraulic charger, M5 ----

a. Maintenance of the charger consists mainly of replacing worn or broken parts and of cleaning and oiling daily and after firing.

Hydraulic charger, M6 ----

a. Maintenance of the charger involves mostly replacement of worn or broken parts and cleaning and oiling daily and after firing.

Figure 1—51a. Lubrication Instructions.


WAR DEPARTMENT LUBRICATION ORDER LO 9-227

GUN, AUTOMATIC, 20-MM, AN-M2; M3.

Figure 1—52. War Department Lubrication Order LO 9-227.

Because of the extremely low temperatures prevailing at high altitudes, only a thin film of lubricant is applied before flights. At other times, the lubricant may be applied freely but excessive and wasteful practices should be avoided. Excessive lubrication will result in dust accumulations on some moving parts and cause wear and malfunctioning.

7. LUBRICATION ORDER

Reproduction of War Department Lubrication Order LO-9-227 (Figure 1-52) prescribes first- and second-echelon lubrication maintenance. A lubrication order is placed on, or issued with, each item of materiel and is to be carried with it at all times (Figure 1-53). In the event the materiel is received without an order, a replacement is requisitioned in conformance with instructions and lists in FM 21-6.

8. LUBRICATION UNDER NORMAL AND UNUSUAL CONDITIONS

The bore should be cleaned with rifle-bore cleaner after firing and on three consecutive days thereafter. After the fourth cleaning, it is dried, reoiled with preservative lubricating oil (medium) above 0°F. and wiped clean before firing. When the gun is not being fired, the oil film should be renewed every five days, using preservative lubricating oil (special) below 0°F.

Caution: The bore and chamber should not be oiled before firing as dangerous pressures may develop.

INSTRUCTIONS FOR DECALCOMANIA APPLICATION AND MOUNTING OF LUBRICATION ORDER

LO 9-227

1. DECALCOMANIA APPLICATION INSTRUCTIONS.

a. Brush or wipe a light coating of VARNISH, spar, clear, water-resisting or LACQUER, spraying over surface to which the decalcomania is to be applied.

b. Dip decalcomania in water until surface will separate from the backing freely, then then slide decalcomania into designated position.

c. Slide backing paper against face of decalcomania and rub surface with a light, even pressure to eliminate air bubbles.

d. Clean around edges with SOLVENT, dry cleaning.

2. INSTRUCTIONS FOR MOUNTING.

a. Locate on rear buffer housing.

Figure 1—53. Instructions for Decalcomania Application and Mounting of Lubrication Order.

The following points are cleaned with rifle-bore cleaner and lubricated with preservative lubricating oil (special), daily and after firing:

Breechblock group.

Receiver.

Cradle.

Exposed unpainted metal surfaces.

Preservative lubricating oil (medium) is used for the following conditions:

Salt air areas.

Extremely high humidity or other excessively moist conditions.

9. INTERVALS

Lubrication intervals should be reduced whenever the daily inspection reveals evidence of the formation of rust. It usually will be necessary to reduce the intervals when operating in areas characterized by high temperatures, dust, and sand in the atmosphere, or high humidity.

10. MAINTENANCE OF THE GROUPS

Cradle Group

The cradle should be inspected carefully for damaged or loose parts. If parts are allowed to work loose, the mounting holes in the cradle will soon become elongated and render the cradle unserviceable.

The anchor support bracket is tested to see whether the screws have worked loose. If this condition exists the locking wire should be cut, the screws retightened, and secured with new wire.

The rollers are oiled and a check made for chips, cracks and for free rotation. If the rollers bind or are chipped and cracked, the cradle is replaced.

Trunnion blocks and screws are inspected for wear or defects and replaced if necessary.

The tightness of the mounting bracket is tested by tapping the bracket lightly on either end with a hammer. If the bracket is loose, the cradle should be replaced.

The threads in the bracket should be chased out if necessary (ordnance maintenance personnel only).

Rear Buffer and Driving Spring Group

Maintenance by Using Arms. The rear buffer is examined for rough or bruised surfaces on dovetail connections. All rough spots are removed with crocus cloth or fine oilstone to make a good push fit with the receiver. If the fit is too tight, it will tend to spread the receiver; if too loose, it will cause the buffer to hammer the receiver.

The dovetail surfaces are wiped clean with a dry cloth but the rear buffer should not be dipped in any prescribed cleaning fluid. It is lubricated with graphite at the time of assembly; fluid will wash out the graphite and thus impair the functioning of the buffer.

The functioning of the rear buffer lock should be checked. If the lock malfunctions or if the buffer is otherwise damaged, the rear buffer is replaced. All burrs should be removed from the lock plunger but no more metal should be taken off than is absolutely necessary; removal of excess metal will cause the plunger to fit loosely and allow the rear buffer to move vertically in the receiver.

The retainer assembly is examined to determine whether the pin or face of the retainer is broken, bent, or missing. If any of these conditions exist, the retainer should be replaced.

If the threads on the driving spring guide are mutilated or excessively worn, the guide is replaced.

The guide tube is checked for looseness in the head and for deformation. If loose or bent, the guide must be replaced.

The driving spring is examined for any sharp kinks or offset of coils which might cause binding or excess friction; if these conditions exist or if free length is less than 23.5 inches the spring is replaced.

The driving spring guide plunger is checked for straightness, general condition, cracks or indications of fracture just in the rear of the head. The plunger should move freely in and out of the guide; if it is bent or shows cracks, it must be replaced.

Maintenance by Ordnance Maintenance Personnel. Maintenance operations given above are performed whenever necessary.

To check for a broken rear buffer spring a burst of ten or fifteen rounds is fired. If the rear buffer becomes heated, the spring is broken and the rear buffer assembly should be replaced.

Functioning of the rear buffer lock spring is checked. If it is weak or broken, the lock plunger pin should be driven out, the lock collar, plunger and spring removed, the spring replaced, and assembled.

Magazine Slide Group

Maintenance by Using Arms. Movement of the magazine slide on the receiver is checked. Any burrs which may exist on guideways of the slide are removed. If the magazine moves with excessive sideplay, the slide must be replaced.

Functioning of the magazine latch springs is examined. If springs are weak, the free length is checked and replaced if necessary.

The free length of the ejector springs is examined and replaced if necessary.

Maintenance by Ordnance Maintenance Personnel. Maintenance operations as given above are performed when required.

The threaded holes in the magazine slide are replaced whenever necessary.

If the ejector stud is damaged or loose, the ejector stud pin should be driven out, the ejector is unscrewed, and the condition of threads in ejector is examined. If necessary, ejector and pin is replaced securely.

Breechblock Group

Maintenance by Using Arms. Freedom of movement of the breechblock in the receiver is checked.

The breechblock is then disassembled and cleaned.

The front face of the bolt is examined for erosion and wear and the condition of the firing pin hole is noted. If it is enlarged sufficiently to cause blown primers, the bolt must be replaced.

If longitudinal shoulders of the bolt (Figure 1-11) are cracked, the bolt should be replaced.

All burrs and rough spots should be removed from surfaces of the bolt.

The breechblock slides are examined for burrs or rough surfaces on the cam; burrs or rough surfaces should be removed. A check is made for swedging near the front end of the slot for the inertia block (Figure 1-54). The cam surface is examined for cracks.

Movement of firing pin in bolt is examined and any burrs are removed. The firing pin is examined for pitting deformation or cracks. If the firing pin is broken or bent, it should be replaced.

Inertia blocks are examined for general condition. Movement of blocks in breechblock slides is checked and any burrs or rough spots are removed.

The breechblock lock is examined carefully for condition of cams on both sides, for wear or roughness on hinging locking surfaces, and the under side for wear.

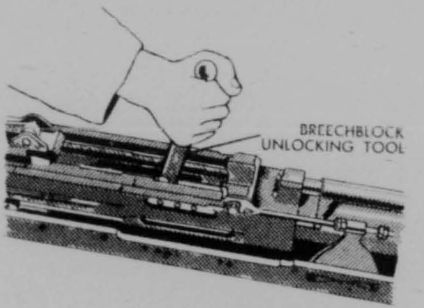


Figure 1—54. Unlocking Breechblock.

Tension of the breechblock slide springs is tested and replaced if broken or shorter than allowable free length.

Sear Mechanism. The sear mechanism is examined for general condition, and for wear or roughness on the surface.

The plunger is checked for burrs or rough surfaces around the disassembling recesses. All rough spots and burrs should be removed.

Tension of sear buffer springs is checked; if they are broken or shorter than the allowable free length they must be replaced.

Maintenance by Ordnance Maintenance Personnel. Maintenance operations are performed as described in preceding paragraphs.

The diameter of firing pin hole is measured (it should be 0.156 inch + 0.004). A No. 22 (0.157) standard drill can be used to clean the firing pin hole to proper size.

The firing pin protrusion also is measured. If the protrusion is less than the prescribed 0.100 to 0.110 inch it should be discarded.

Condition of the breechblock slide key is examined to determine whether the taper pin is in place or loose. If the taper pin in the key is loose, it should be replaced with a new pin.

If the breechblock pins are loose or damaged, the breechblock taper pins should be driven out and the breechblock pins and taper pins replaced.

Radius of sear at point indicated by arrow in Figure 1-12 should be measured. If the radius is less than 0.04 inch, the sear must be replaced.

Gas Cylinder Sleeve Group

Maintenance by Using Arms. All parts are examined for condition. If the sleeve is bent, it should be replaced.

Tension of gas cylinder sleeve spring is checked; if it is kinked or shorter than allowable free length, it must be replaced.

Movement of the gas cylinder sleeve guide in the sleeve is checked. The guide should have a medium close fit in the sleeve; if clearance is excessive, replacement is necessary.

If the gas cylinder vent plug is loose it must be replaced. When replacing the vent plug, the new type (larger vent hole) should be used. This new plug can be identified by the part number B7229626 stamped on its face.

All carbon and any other foreign matter should be removed from the cylinder, piston, bracket, and plugs.

All burrs should be eliminated from the piston. If excessively burred, it will be necessary to replace gas cylinder sleeve with piston.

Movement of push rods in their recesses in the receiver is checked and all burrs are removed from push rods.

Maintenance by Ordnance Maintenance Personnel. Maintenance operations are performed as described in preceding paragraphs.

Guns which were converted to the T31 (M3) included both long and short chamber tubes. To provide proper chamber length, approximately two threads of length were removed from the long chamber tube before installation in the weapon. This resulted in a misalignment between the tube gas port and the bracket gas port. This was originally compensated for by applying a 0.06 x 45 degree chamfer to the bracket gas port. The chamfer was found to be insufficient in all cases, occasionally resulting in a slow rate of fire. The deficiency was corrected in February 1945 by applying a 0.10 x 45 degree chamfer to the bracket gas port. The rate of fire of guns with the converted long chamber tube, if found to be slow as a result of incorrect port alignment, can be increased by removing the gas cylinder bracket and applying a chamfer of 0.10 x 45 degrees.

Recoil Group

Maintenance. All parts are washed in a dry-cleaning solvent with the exception of the recoil housing assembly.

Note: Ring spring assemblies are lubricated at initial assembly and must not be immersed in cleaning solvents. The outside of the housing is cleaned with a dry cloth, and the sleeves inspected in both ends for proper staking. If the recoil housing assembly is damaged, no attempt should be made to repair it; instead, it should be replaced.

The helical recoil spring should not show any evidence of buckling and its free height should be 5¼ inches (plus or minus 10 per cent). If it does not meet these dimensions, it should not be reinstalled.

The gas cylinder bracket should be cleaned and all particles of carbon and burnt powder removed. All rough spots are removed with an oil stone. The opening at the rear of the gas cylinder bracket, in which the gas cylinder seats, must be perfectly formed. Any mutilation or deposit in this opening would greatly impair the operation of the gas cylinder group.

The threads of the gas cylinder bracket nut are inspected. This nut is run up on the threads of the tube by hand to test the condition of the threads. If the thread fit is not satisfactory, it must be replaced.

11. MALFUNCTIONS AND CORRECTIONS

Misfire

General. All stoppages are considered misfires if the receiver is not visible. Immediately after the occurrence of a misfire, the procedure is as outlined below.

Ground Testing. Thirty seconds after the misfire the gun is recharged and the round removed from the vicinity of the aircraft.

Caution: If the gun is hot and the round cannot be removed from the chamber, the breechblock should be closed. It should not be opened until the hand can be placed on the breech or barrel without discomfort.

Air Testing. If the weapon can be recharged, the procedure is the same as for ground testing, described above. If the weapon cannot be recharged, no corrective action is possible.

Note: The possibility of a hangfire of more than thirty seconds after an attempt to fire is very remote in guns using fixed ammunition. The possibility of the propellent or the high-explosive filler being fired by the heat absorbed from a hot gun barrel increases with the length of time the round is in the gun. The safest time to remove a misfire is between thirty to forty-five seconds after its occurrence.

Failure to Fire Chambered Round

Causes: Defective firing pin; defective ammunition; weak or broken driving spring.

Remedies. Immediately after landing, the round is extracted and examined. If the primer of the round is deeply indented, it must be treated as a misfire and immersed in water. If the primer is not indented or only slightly indented, the firing pin is examined as below.

If the firing pin is cracked or broken, it should be replaced. A weak or broken driving spring also must be replaced.

The slide springs are inspected and the receiver is checked for foreign matter. The breechblock slides are examined for swedging which may produce "light hits" by interfering with breechblock action. All obstructions should be removed.

Failure to Feed

The following instructions pertain to feed failures regardless of the type of feed mechanism used, unless otherwise indicated.

Causes: Improper adjustment of magazine (or feed) slide.

Broken components of magazine slide anchor parts.

Deformed or burred feed mouth.

Excessive friction in feed mechanism.

Broken belt or belt jam in ammunition box or feed chute.

Link jam in link chute.

Insufficient recoil of breechblock caused by faulty unlocking or defective ammunition.

Insufficient voltage (feed mechanism M3).

Faulty electrical connections (feed mechanism M3).

Defective electric motor (feed mechanism M3).

Clutch not adjusted (feed mechanism M3).

Loss of tension of driving spring (feed mechanism AN-M2).

Remedies. Adjustment of magazine (or feed) slide correctly.

Tightening of loose components and replacement of broken components of magazine slide anchor parts.

Removal of all burrs from feed mouth, using a fine oilstone or crocus cloth. (If mouth is deformed, feed mechanism should be replaced.) Checking movement of operating parts and lubricating if friction is excessive.

Checking ammunition box and feed chute for jammed links or rounds. Replacement of defective links, rounds, or feed chutes, if necessary.

Checking for jammed links in link chute. Remove jammed links. **Caution:** The finger should not be inserted into the adapter of the feed mechanism AN-M2 to remove a jammed link.

If gun fails to pick up a new round, the procedure is as follows:

The magazine (or feed) slide is adjusted.

The bore is checked to see that there is no round in the chamber.

The gas-cylinder sleeve and piston is checked for free operation. Burrs and dirt are removed from piston and sleeve.

If the piston is deformed or bent on the end, it should be replaced.

Burrs are removed from the breechblock and from interior surfaces of the receiver.

If the voltage is insufficient to operate feed mechanism M3, ordnance maintenance personnel should be notified.

Wiring is checked for proper connections and grounding (feed mechanism M3).

If electric motor of feed mechanism does not function properly, ordnance maintenance personnel should be notified.

The clutch of feed mechanism M3 should be adjusted.

Failure to Extract

Causes: Carbon deposit in chamber or dirty ammunition.

Remedies. When failure to extract occurs, the bolt may be found fully closed with a spent case in the chamber. Generally, most failures to extract can be remedied by charging the gun, except when the extractor, extractor spring, or extractor pin are broken. When this occurs, the case should be pushed out from the muzzle end. The broken extractor, spring, or pin should be replaced.

Sometimes the empty case will be left in the chamber with the extractor ripping through the base of the cartridge case. When this occurs, the bolt will generally attempt to feed a fresh round into the chamber. It will then be necessary to remove this round before the spent case can be removed. If the jammed round is broken, all powder that may be strewn around in the receiver must be removed.

A dirty chamber can be caused by carbon deposit from the oil film on the rounds. If this occurs, the chamber should be cleaned.

Failure to Eject, Feed Mechanism AN-M2

Causes: Broken ejector stud or broken ejector.

Remedy: The ejector must be replaced.

Failure to Eject, Feed Mechanism M3

Cause: Broken ejector.

Remedy: Replacement of the ejector.

Runaway Gun

Causes: Defective firing switch (if used); broken sear, or broken and weak sear spring; jamming of solenoid plunger in sleeve (AN-M1A1 trigger).

Remedies: If firing switch (if used) is defective, ordnance maintenance personnel should be notified.

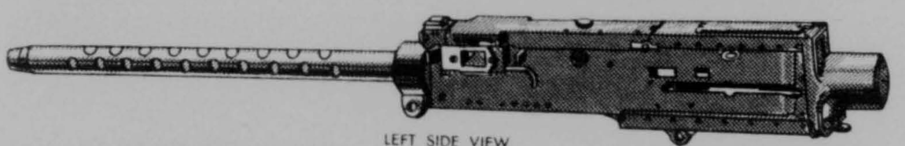
If sear or sear spring is broken, it must be replaced.

If solenoid plunger jams, the trigger must be replaced.

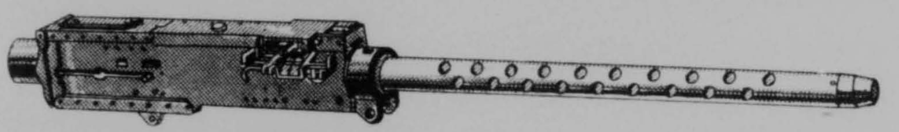
Slow Firing Gun

If the gun fires at a rate of below 650 rounds per minute, it should be turned over to ordnance maintenance personnel.

CHAPTER 2—BASIC AIRCRAFT MACHINE GUN CAL. 50 M3



LEFT SIDE VIEW



RIGHT SIDE VIEW

SECTION I—GENERAL

1. DESCRIPTION

The aircraft machine gun, cal. .50, M3, is essentially the same in general appearance and manner function as the basic aircraft Browning machine gun, cal. .50, M2. It is a recoil-operated, belt-fed, air-cooled machine gun. A metallic link, disintegrating belt is used in all firing of the gun. By properly repositioning some of the component parts, the gun may be fed from either the right or left side.

Differences in Models M3 and M2

The basic aircraft machine gun, cal. .50, M3 differs from the basic aircraft Browning machine gun, cal. .50, M2, as follows:

A **recoil booster** (Figure 2-1) is substituted for the front-barrel bearing.

A new design **cover group** (Figure 2-2) is substituted for the M2 cover group. The cover, which differs slightly in shape from the M2 design, houses a new belt-feed slide assembly with slide retainer, wider belt-feed pawl with two springs, a new cover extractor cam which is steeper than the M2 cam, a new cover extractor spring, and a more rigid belt-feed lever.

The **backplate** (Figure 2-3) has been redesigned to extend around the side plates. Washer springs (Belleville type) are used in the buffer tube in place of fiber disks now used in the gun M2.

The outer driving spring has been changed by removing two of the solid wound coils from each end.

The inner driving spring has been altered by removing three coils from each end.

The **bolt** (Figure 2-4) has been lightened, and has an integral accelerator stop (Figure 2-5), to take the same notched breech lock as the gun M2.

The **cocking lever** (Figure 2-6) has been redesigned to provide thicker cross sections and to eliminate sharp corners. In addition, a

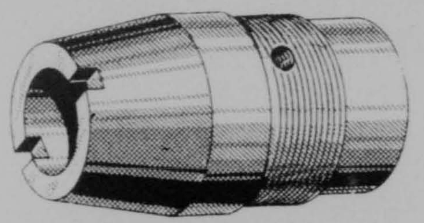


Figure 2—1. Recoil Booster.

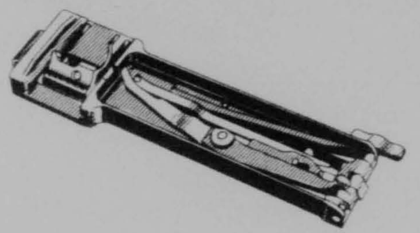


Figure 2—2. Cover Group.

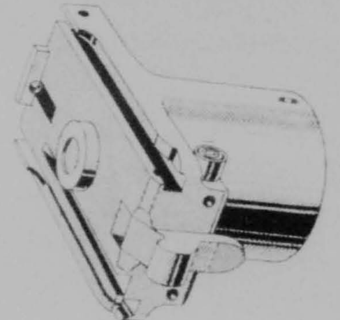


Figure 2—3. Backplate Group—Front and Bottom View.

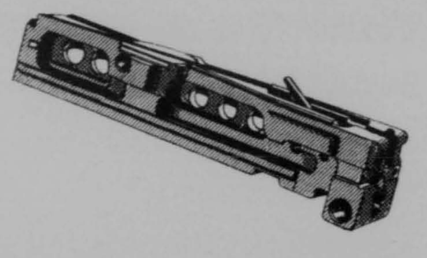


Figure 2—4. Bolt Group with Extractor Assembly Removed.

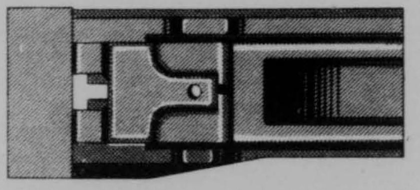


Figure 2—5. Rear End of Bolt Showing Integral Accelerator Stop—Bottom View.

The **sear** (Figure 2-6) has been redesigned to increase its strength and to increase reliability of firing-pin retention. The sear spring is larger and seats over a lug on the bottom of the sear.

The **sear slide** has been redesigned to eliminate the V-shaped notch; an elongated pin hole has been added for retention in the bolt.

A sear-slide stop pin has been added to retain the sear slide in the bolt.

The **firing pin** is stronger and has a larger point (Figure 2-6).

The **bolt switch** has been changed to provide an interlocking tongue on the under side.

The **extractor assembly** has been redesigned so that the position of the ejector may be shifted to facilitate feeding from either side of the gun.

A firing pin spring-stop assembly replaces the sear-stop assembly of the gun M2. When assembled, it acts as a bearing point for compression of the firing-pin spring. The sear is retained in the bolt by the sear slide.

A longer-life barrel is used. (Recently designed M2 barrels are similar.)

shoulder has been added to the lever to facilitate proper assembly.

The cocking-lever pin has been redesigned so that it may be assembled from either side of the bolt and to retain the sear-slide stop pin.

A cocking-lever stop which is housed in the cocking-lever slot in the top of the bolt has been added to cushion the lever.

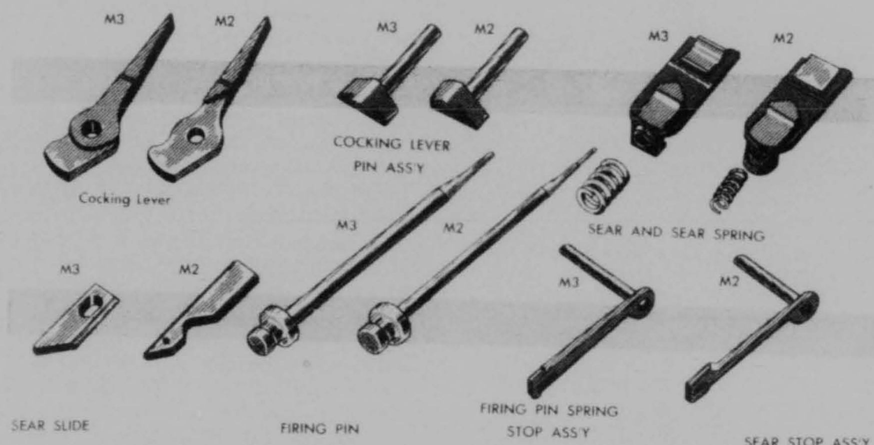


Figure 2—6. Comparison of Similar Bolt Group Parts for Guns M3 and M2.

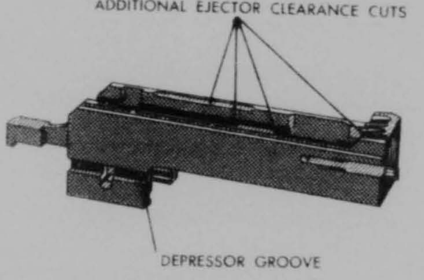


Figure 2—7. Barrel Extension Group.

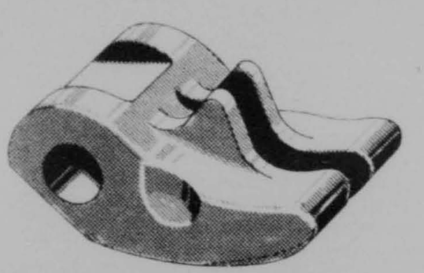


Figure 2—8. Accelerator—Dotted Lines Indicate Shape of Accelerator for Gun M2.

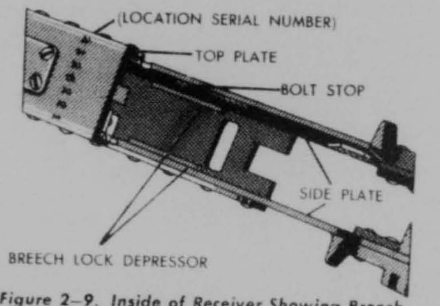


Figure 2—9. Inside of Receiver Showing Breech Lock Depressors—Top View.

The **barrel extension** (Figure 2-7) has been changed by providing additionai clearance cuts for the ejector, and the breech lock depressor slots are milled across the entire side.

A new air and washer-spring type of **barrel-buffer assembly** is used in place of an oil-buffer assembly. A barrel-buffer tube-lock assembly is similar to the oil buffer tube-lock assembly of the gun M2, but serves only to position the accelerator. There are no locking serrations on the buffer tube, nor a lug on the lock.

The **accelerator** (Figure 2-8) has been redesigned by changing the curvature of the claw end.

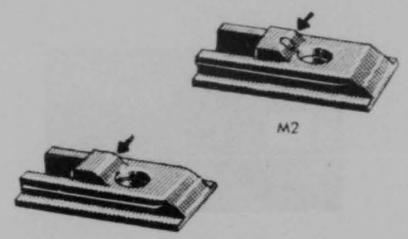


Figure 2—10. Comparison of Breech Lock Cams for Guns M3 and M2.

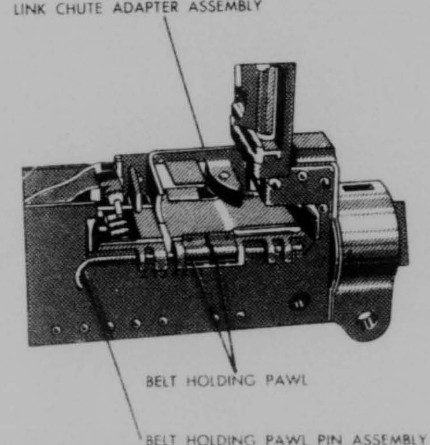


Figure 2—11. Feedway Section of Receiver—Parts Assembled for Right-Hand Feed.

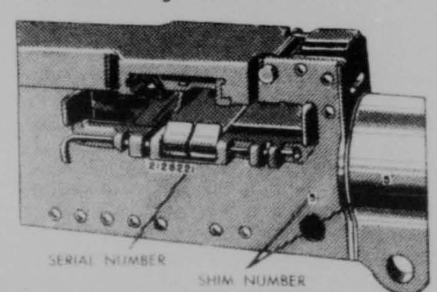


Figure 2—12. Location of Serial and Trunnion Block Shim Numbers.

The **(extractor) switch** has been made shorter than the M2 switch and the slope of the camming faces has been changed. The switch spring is slightly heavier.

The **extractor cam** has been widened, thus causing earlier rise of the extractor.

The **breech-lock depressors** are securely fastened to the side plates (Figure 2-9). On the gun M2 the depressors are attached to the oil-buffer body. The depressors have a curved camming surface formed on the front end.

The **breech lock cam** has been changed to add a radius at the top of the camming step (Figure 2-10).

A **link-chute adapter assembly** (Figure 2-11) takes the place of front and rear cartridge stops and link stripper of the gun M2. A split belt-holding pawl is used as on the gun M2.

A spring-type **recoil adapter** is used in some installations in place of the trunnion adapter.

The **trigger bar** has been made shorter at the rear end than that of the M2 gun.

Identification Information

One **serial number** is required for records concerning these weapons. The serial number is located on the right side plate just below the feedway (Figure 2-12) and on the top plate (Figure 2-9). The size of the trunnion-block shim used at manufacture is stamped on the side plate and trunnion adapter (Figure 2-12).

2. NOMENCLATURE

Backplate Group

The backplate group (Figure 2-14) is an assembly attached to the rear end of the receiver assembly. In general, the group is composed of the backplate, latch lock, and buffer components. The plate slides downward into grooves inside the receiver side plates and surrounds the outside of the side plates to prevent spreading. The backplate is held in position, when assembled, by the **latch** engaging the bottom plate of the receiver. The latch is prevented from disengaging by the transverse latch lock. Both latch and lock are spring operated.

Data pertaining to aircraft machine gun, cal. .50, M3:

a. GENERAL.

Weight of gun	64.60 lb.
Weight of equipment:	
Recoil adapter assembly	4.25 lb.
Weight of barrel	9.80 lb.
Length over-all	57.20 in.
Length of barrel	36.00 in.
Rifling:	
Length	34.14 in.
Number of grooves	8
Twist (direction)	Right-hand.
Twist (one turn in)	15.00 in.
Operation	Recoil.
Feed	Disintegrating link belt.
Capacity of feeding device	As desired.
Sights	Not furnished by Ordnance Department.
Firing pin release:	
Pressure applied to sear slide	35 lb. max.
Pressure applied to sear	23 lb. max.
[1] Belt pull	35 lb. min.
Cooling	Air
Ammunition	For complete ammunition data, see section XXIII

b. PERFORMANCE.

Rate of fire	1150-1250 rds. per minute
[2] Maximum number of rounds (in single burst) which can be fired without danger of cook-off before cooling	150 rounds
Average accuracy life of barrel	5,000 rounds

[1] The "belt pull" of the gun is an expression used to indicate the maximum belt load that can be imposed on the gun without obtaining misfeeds. It is measured by hanging a weight at the end of a belt of 10 live rounds and 2 dummy rounds by means of a cable and special ordnance equipment known as the belt feed test spring.

[2] See cook-off and barrel life data in paragraph 21c.

Figure 2—13. Tabulated Data.

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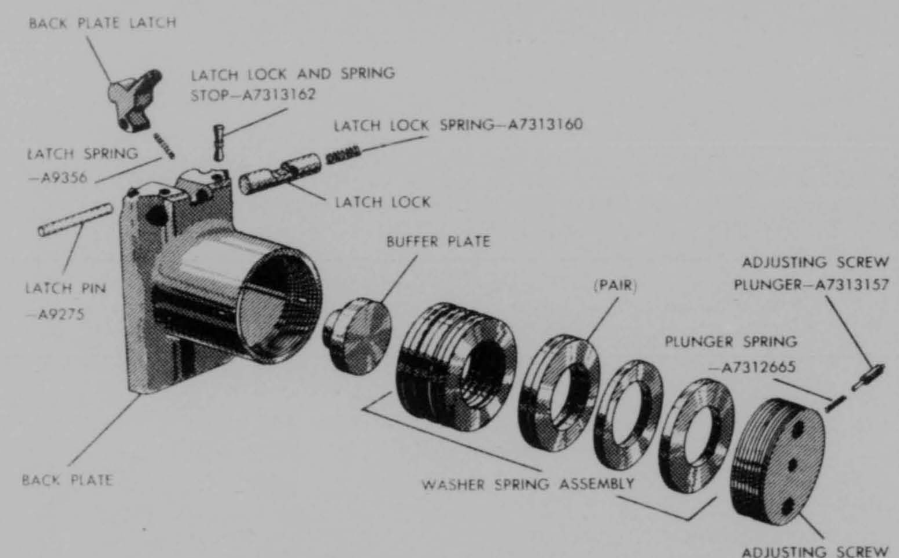

Figure 2–14. Backplate Assembly—Exploded View—Right Side and Bottom.

An integral cylinder projecting rearward from the backplate houses a buffer plate and ten cup-shaped washer springs (Belleville type) assembled in pairs and held in place by an adjusting screw which is threaded into the rear end of the cylinder. The buffer plate bears upon the washers and projects through the front face of the backplate. A spring-loaded plunger seating in the adjusting screw and a slot in the cylinder prevents the screw from backing out.

The main function of the backplate is to stop and cushion the bolt on the recoil movement. The bolt strikes the projecting buffer plate which bears upon the washer springs. These springs, which are slightly compressed at assembly, cushion the blow and store up part of the recoil energy and return it to the bolt to speed up the counterrecoil. The backplate also acts as a stop for the barrel-buffer group, and the rear end of the driving-spring rod assembly which bears in a groove in the backplate when assembled.

Bolt Group

The bolt group (Figure 2-15) contains the firing and extracting mechanisms of the gun and actuates the belt-feed mechanism in the cover. In general it is composed of the bolt assembly, sear, sear slide, cocking lever, firing-pin group, and extractor assembly, and houses the driving-spring group, when assembled. The bolt slides in ways which are cut in the barrel extension, and is locked to it, holding the cartridge in the chamber of the barrel, when firing, by the breech lock in the barrel extension. The bolt withdraws the fired cartridge from the chamber by means of the T-slot in the front end, in which the cartridge is seated when chambered.

The sear slides vertically in grooves in the rear end of the bolt, is actuated by a spring which seats on a lug on the sear and in a seat in the bolt, and is retained in the bolt by the sear slide. The sear slide is assembled in lateral grooves in the rear face of the bolt, is held in place by a retaining pin, and acts upon a lug on the sear. The purpose of the sear is to hold the firing-pin group in the cocked position when cocked by the cocking lever.

The cocking lever is pivoted vertically in a slot in the rear part of the bolt on a transverse

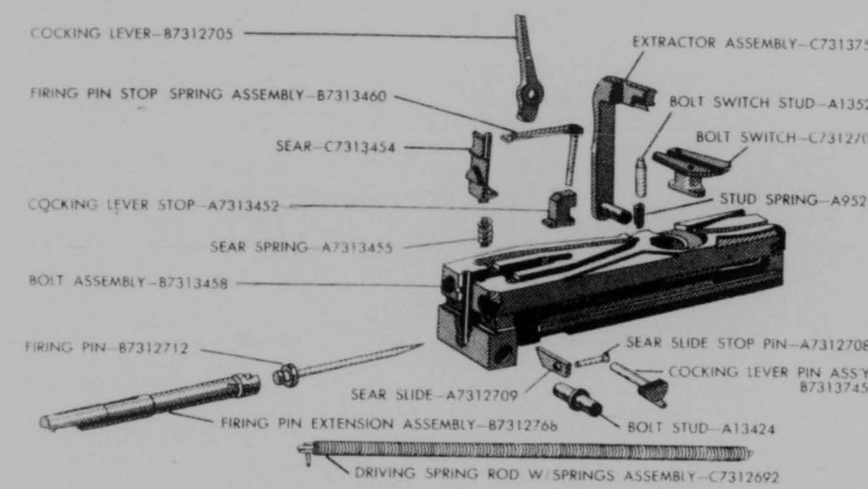

Figure 2–15. Bolt Group—Exploded View.

cocking-lever pin. A rubber stop, seated in the bolt ahead of the cocking lever, cushions the lever on its forward movement. The upper end of the lever projects above the bolt and the lower end engages in a slot in the firing-pin extension. The cocking lever cocks the firing-pin group when its upper end is cammed forward by the top-plate bracket on the top plate of the receiver, during recoil of the bolt.

The firing-pin extension, assembled to the firing pin, is housed in a longitudinal tunnel in the bolt and contains the firing-pin spring, the rear end of which bears upon a stop pin extending vertically through the bolt and a slot in the cocking lever extension, when assembled.

The extractor assembly, which contains the extractor and ejector, is pivoted in the left side of the bolt and can be assembled for either right- or left-hand feeding of ammunition. A stop lug on the bolt limits the downward movement of the extractor assembly. The extractor assembly extracts a cartridge from the belt, and guides it into the T-slot in the bolt and thence into the chamber of the barrel.

Two diagonal grooves, or ways, in the top of the bolt seat the rear end of the belt-feed lever assembly in the cover, when the cover is closed. The bolt switch seats in a circular recess in the top of the bolt and is furnished with a groove similar to the bolt grooves. The switch may be positioned on a spring-loaded stud to make either of the bolt grooves continuous. The switch is retained in the bolt by an undercut in its seating recess.

The driving-spring rod with spring assembly is housed in a longitudinal tunnel in the bolt. A shoulder at the forward end of the tunnel acts as a bearing for the springs to compress them against a shoulder on the rear end of the rod when the bolt moves rearward.

The bottom of the bolt is designed to prevent the accelerator claws from entering the transverse breech-lock notch in the bolt (Figure 2-5); this prevents jamming of the bolt. A bolt stud is assembled in a hole in the side of the bolt as a means for retracting the bolt. One end of the stud projects through a slot in the side plate, and is retained by a collar bearing upon the inside of the side plate.

The general function of the bolt group is to load and fire the gun, extract and eject the fired cartridges, and actuate the belt-feed mechanism of the gun through the medium of the belt-feed lever in the cover group. The

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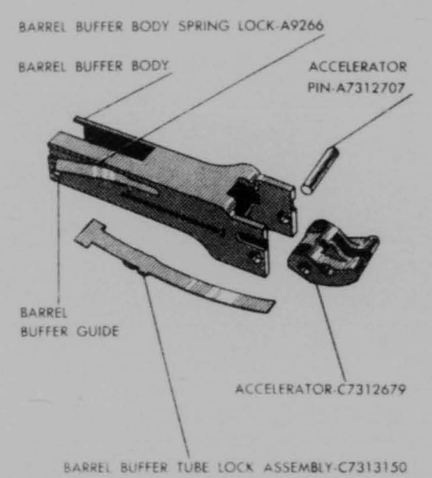

Figure 2—16. Barrel Buffer Body Group—Exploded View.

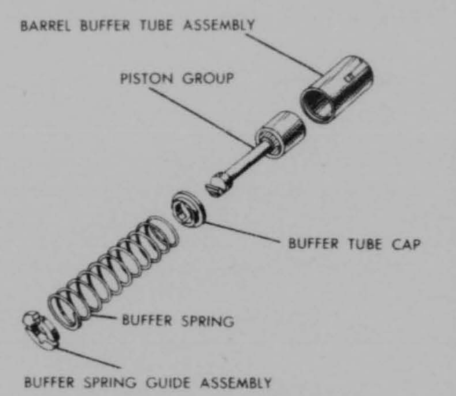

Figure 2—17. Barrel Buffer Assembly C7312663—Partly Exploded View.

driving springs act to return the bolt to the forward position at the end of the recoil movement.

Barrel-buffer Group

The barrel-buffer group (see Figure 2-16) is composed of two main group assemblies; the barrel-buffer body group assembly, which includes the accelerator, and the barrel-buffer assembly with spring and guide. When assembled the buffer assembly is housed in the body which is locked in the rear lower end of the receiver by a leaf spring lock staked in the body and bearing in a recess in the side plate. Guides fastened to the sides of the body at the rear end seat in grooves in the side plates of the receiver to hold it in position. Longitudinal grooves in the sides of the body, at the front end, seat the rear ends of the breech lock depressors fastened to the inner face of the side plates of the receiver. The depressors act as anchors for the front end of the body in addition to their function of unlocking the bolt. A longitudinal slot in the right side of the buffer body acts as a guideway for a key on the spring guide of the barrel-buffer assembly, when assembled, to prevent the piston rod from turning.

The accelerator is pivoted in the front end of the body by a transverse pin. The accelerator is acted upon by the barrel extension during recoil to speed the recoil movement of the bolt. In turn the accelerator locks the barrel extension to the buffer body until released by the bolt on the counterrecoil movement. A tube lock, assembled in the body, bears upon the bottom of the accelerator to hold it in the locked position until released by the bolt.

The barrel-buffer assembly is, in general, composed of a hollow, cylindrical body, called the "tube" (Figure 2-17), open at one end, which is closed by a threaded cap. An air port in the wall of the tube admits air for compression by the piston on the recoil movement. A piston rod, assembled through a hole in the cap, is attached at the rear end to a piston in the tube by a pin. The front end of the rod engages with the barrel extension shank when assembled. A relief valve, spring, and retainer are assembled in the rear end of the piston and held in position by ten cup-shaped washer springs upon which the rear end of the piston rod bears. An elongated pin hole in the piston rod permits the springs to be assembled under slight compression and to act as a buffer for the rod at the end of the

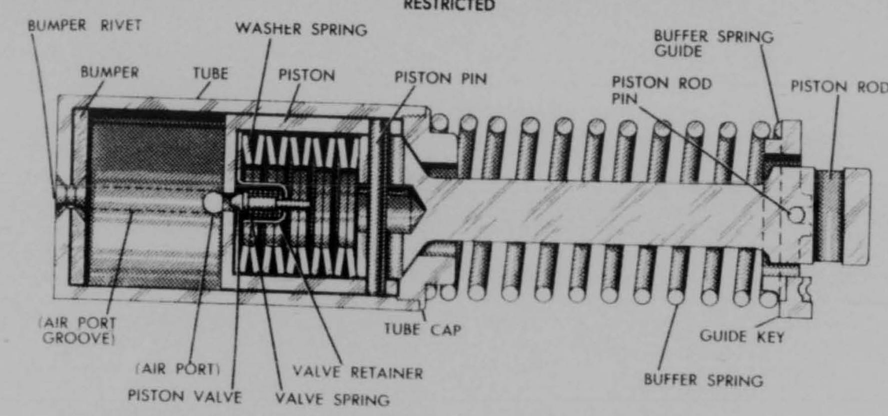

Figure 2—17A. Barrel Buffer Assembly with Piston in Forward Position—Sectional View.

recoil movement of the piston. Figure 2-17a shows a sectional view of the barrel-buffer assembly.

A coil spring is assembled on the piston rod, outside the tube, bearing upon the tube cap, and is held in position under compression by a guide. This guide is in the form of a washer, held in place by a cross pin passing through, and extending from, the forward end of the piston rod, bearing in notches in the guide, when assembled. A key in the side of the guide engaging in a slot in the buffer body, when assembled, prevents the piston from turning during operation.

The barrel-buffer group has four main functions: (1) to bring the barrel and barrel extension to rest and hold it, on the recoil movement, and to cushion the shock, (2) to transmit recoil energy of the barrel and barrel extension through the accelerator to speed up the recoil of the bolt, (3) to return the barrel and barrel extension to the forward "battery" position by means of the expanding buffer spring assisted by the accelerator acted upon by the bolt, (4) through the medium of the accelerator, to time the movements of the barrel, barrel extension, and bolt for locking of the bolt to the barrel extension during counterrecoil.

Barrel and Barrel-extension Group

The barrel is cylindrical (Figures 2-18 and 2-19), and threaded at the rear end to screw

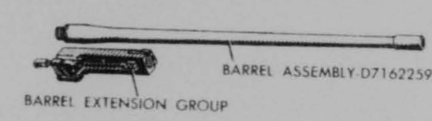

Figure 2—18. Barrel and Barrel Extension Group—Barrel Removed.

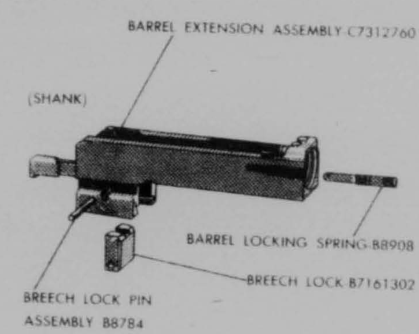

Figure 2—19. Barrel Extension Group—Exploded View.

into the barrel extension loosely enough for easy adjustment. Just forward of this thread, serrations are cut around the periphery for engagement of the barrel-locking spring which holds the barrel in adjustment, with regard to headspace, when assembled to the barrel extension. A cylindrical sleeve is fastened to the muzzle end of the barrel for en-

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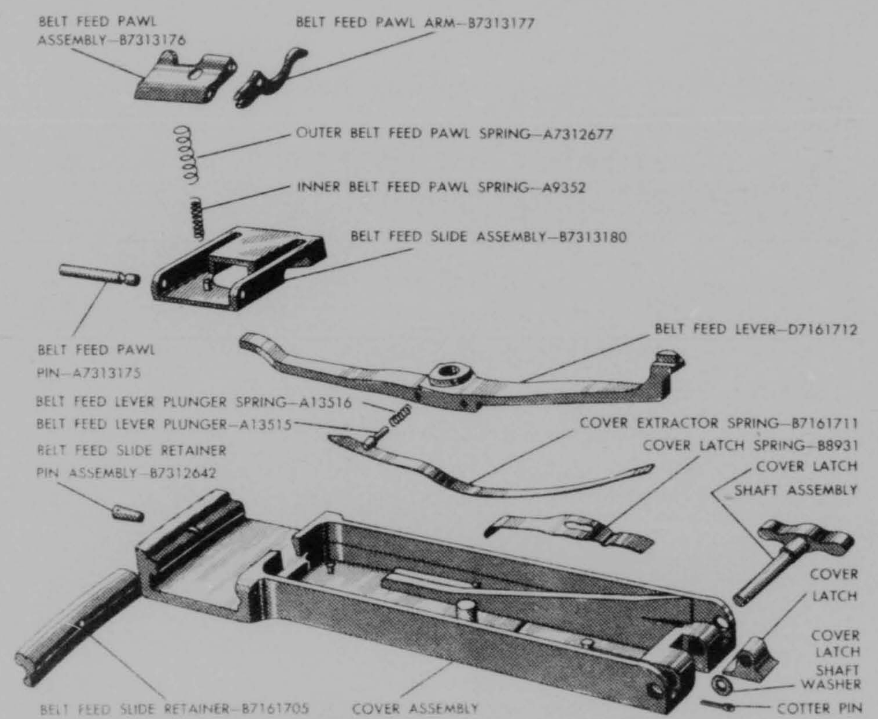

Figure 2–20. Cover Group—Exploded View.

gagement in the bearing formed by the recoil booster in the barrel jacket of the receiver group, when assembled. The bore of the barrel is chromium-plated to increase accuracy and has a special liner assembled near the breech end to increase the velocity.

The barrel extension extends to the rear of the barrel, when they are assembled. Its forward end is a formed lug, drilled and threaded, into which the barrel is screwed. Integral side members extend rearward, terminating in lugs pointing downward and carrying the breech lock. At the rear end is the barrel-extension shank, pinned in position between the side members. The shank terminates in a hook and extends rearward to engage a similar hook on the piston rod of the barrel buffer, when assembled. Grooves, cut in the side members of the barrel extension, support and form a slideway for the bolt, when assembled. Cuts in the upper inside edges of the side members, and the top of the forward portion into which the barrel is screwed, provide clearance for the extractor assembly of the bolt when assembled for either right- or left-hand feed.

The breech lock slides vertically in grooves in the rear part of the barrel extension and is retained by a pin passing laterally through the breech lock and elongated holes in the side members of the extension. The barrel-locking spring is staked in an undercut groove

in the right side of the extension, at the forward end.

The function of the barrel is to house the cartridge and direct the bullet when fired. The barrel is rifled to rotate the bullet, which helps maintain direction and prevent tumbling.

The function of the barrel-extension group is to support the rear end of the barrel and maintain its adjustment, with regard to headspace, by means of the barrel-locking spring. The extension is, in turn, supported by the breech-lock cam in the receiver. The extension also supports the bolt, forms a slideway for it during operation and provides a means for locking the bolt to the barrel during firing of the cartridge. The extension shank, engaging with the piston rod of the barrel buffer, operates the piston, compresses the buffer spring on the recoil movement, and is in turn forced forward by the expanding spring on the counterrecoil movement. The breech lock, acted upon by the breech-lock cam on the forward movement of the extension and by the breech-lock depressors on the rearward movement, locks and unlocks the bolt with respect to the barrel extension. The extension also acts upon the accelerator in the barrel-buffer body to accelerate the rearward movement of the bolt.

Cover Group

The cover group (Figure 2-20) carries the feeding mechanism of the gun, and is operated by the bolt through the medium of the belt-feed lever. The group, in general, is composed of the cover, belt-feed slide group, cover-extractor cam, cover-extractor spring, and belt-feed lever.

The cover hinges in the trunnion block, pivoting on the cover pin. It is held by a spring-loaded cover detent seated in the trunnion block and latched by the cover latch engaging under the top plate when the cover is closed. The cover-extractor cam is fastened to the left inner side of the cover. The cover-extractor spring is secured beside the cam by means of a headed stud engaging in a slot in the spring, and by an undercut in the cam. The cover latch spring, assembled to the right of the extractor spring by means of a headed stud and slot, holds the cover-extractor spring in position, and places spring pressure on the latch.

The belt-feed lever is pivoted at the middle on a stud in the cover. The forward end engages in a slot in the belt-feed slide, and a lug on the rear end engages in one of the two camming grooves in the top of the bolt when the cover is closed. A spring-loaded plunger is housed in one of two wells in the side of the lever and bears on the side plate to position the lever when the cover is open, so that the lug on the rear end will properly engage one of the two camming grooves in the bolt, for right- or left-hand feed, when the cover is closed.

The belt-feed slide group contains the feed pawl and pawl arm pivoted in the slide, which moves laterally in the guideways in the forward section of the cover and is held in place by a retainer fastened by a pin. The pawl is spring-operated by an inner and outer spring seating in the slide and pawl. The pawl arm is positioned on the pawl by a spring-loaded plunger in the pawl, and retains the pawl pin through the medium of a notch in the end of the arm seating in a groove in the pin, when assembled. The slide group and lever may be assembled for either right- or left-hand feed by positioning of parts as explained in this manual.

The function of the cover group is to pull the ammunition belt into the gun, position a cartridge in the feedway and assist the extractor of the bolt group to withdraw a cartridge from the belt, position it in the T-slot of the bolt, and guide it into the chamber of the barrel. The belt-feed slide is operated laterally by the belt-feed lever which is in turn operated by the bolt during recoil and counter-recoil. The rear end of the lever engaging in one of the two diagonal camming grooves in the bolt is moved from side to side as the bolt moves backward and forward. This causes the slide, which is engaged with the front end of the lever, to move laterally. The cover extractor spring bears upon the extractor to force it into the extractor groove of the cartridge awaiting extraction in the feedway. The cover-extractor cam forces the extractor downward against the (extractor) switch in

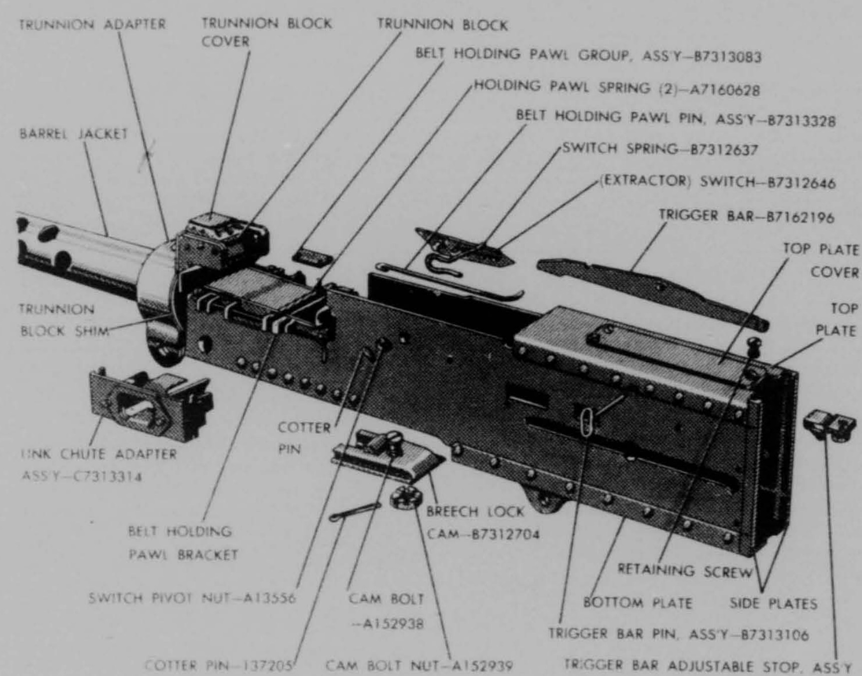

Figure 2–21. Receiver Group—Parts Removed and Shown in Relative Positions.

the receiver, to guide the cartridge into the T-slot in the bolt when extracted from the belt, during the recoil movement of the bolt. The belt-feed pawl arm prevents the feed pawl from engaging the ammunition belt and pulling another round into the feedway, should the cartridge awaiting extraction fail to be extracted; thus it prevents jamming.

Receiver and Barrel-jacket Group

The receiver group (Figure 2-21) consists of the receiver assembly, barrel jacket, and other parts assembled to them. The receiver assembly consists of the trunnion block, two side plates, a bottom plate, top plate and other parts assembled permanently to them. The trunnion block forms the basic part of the receiver assembly. The side plates are attached to the trunnion block and extend rearward. The top and bottom plates are attached to the side plates.

The barrel-jacket assembly contains the breech bearing permanently fastened to the rear end. The breech bearing screws into the trunnion block to support the jacket when assembled. A recoil booster is screwed into the front end of the jacket. The booster acts as a front barrel bearing, and contributes to an increased rate of fire by momentarily confining gas pressure at the muzzle which accelerates recoil of the barrel and barrel-extension group. The breech bearing acts only as a guide for the barrel which is supported at the rear by the barrel extension into which it threads. The barrel extension is in turn supported by the breech-lock cam in the receiver. Holes in the barrel jacket provide ventilation

to dissipate heat from the barrel when the gun is firing.

A lateral feedway for the ammunition belt is cut into the top of the trunnion block and the front-top of the side plates. At the lower edge of the feedway, right- and left-hand belt-holding pawl brackets are riveted to the side plates to support the belt-holding pawls and link-chute adapter, which are secured in the brackets by belt-holding pawl pins. The link-chute adapter contains the cartridge stops and link stripper and guide. A hole bored through the side plates and trunnion block acts as a bearing for the front-gun trunnion pin when mounting the gun in some installations. Two drilled lugs on the bottom plate act as bearings for the rear-gun trunnion pin. A lateral hole bored through the trunnion block at the top-forward end acts as a bearing for the cover pin.

A trunnion adapter, with a lug drilled to form a bearing for the front gun trunnion pin in some installations, is threaded onto the front end of the trunnion block, and held in place by a spring-loaded trunnion block lock housed in the trunnion block. Thread qualification is obtained by use of shims of varying thickness. A recoil adapter, which may be used in place of the trunnion adapter in some installations, is assembled to the trunnion block in a similar manner.

The breech lock cam is fastened to the inner face of the bottom plate by means of a lug on the cam passing through a hole in the plate and secured by a bolt and nut. The cam is grooved at the sides to form a slideway for the barrel extension which it supports. A ramp on the rear end of the cam acts to cam the breech lock upward to lock the bolt, during counterrecoil of the barrel and barrel extension.

The top-plate bracket is fastened to the under side of the top plate and forms a bearing surface which engages the upper end of the cocking lever to operate it during recoil and counterrecoil movements of the bolt. A lateral hole through the bracket and left-hand side plate forms a bearing for the trigger-bar pin which acts as a pivot for the trigger bar, when used. A bolt-latch bracket is fastened to the top plate to the right of the top-plate bracket, but in this gun serves to hold the bolt down. An adjustable trigger-bar stop assembly is fastened to the under side of the top plate to the rear of the bracket, for the purpose of limiting the upward movement of the trigger bar when acted upon by a backplate solenoid, when used. The adjustable stop is positioned on the rear trigger-bar stop (pin) riveted into the top plate, and is retained by a screw extending through the top-plate cover and top plate, and threaded into the body of the adjustable stop.

Breech lock depressors are fastened to the inner faces of the side plates (Figure 2-9). The rear end of these depressors anchor the front end of the barrel-buffer group, when assembled, and the front ends are formed into cams which engage the breech-lock pin in the barrel extension to cam down the breech lock and unlock the bolt during recoil.

The (extractor) switch is pivoted to the inside of the left-hand side plate and positioned by a threaded stud, nut, and spring. The switch, in conjunction with the cover extractor cam in the cover group, assists the extractor to position the cartridge in the T-slot of the bolt. The extractor cam riveted to the side plate, just ahead of the switch, raises the extractor near the end of the counterrecoil movement of the bolt, after the cartridge has been started into the chamber.

The purpose of the receiver group is to house the working mechanism of the gun, as well as to act as a support of the fixed parts which contribute to operation. It also acts, through the barrel jacket, to support and protect the barrel.

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SECTION II—DISASSEMBLY AND ASSEMBLY

1. BACKPLATE GROUP

Removal

The backplate latch lock is pushed in, the backplate latch is pulled up, and the backplate slipped up out of the receiver (Figure 2-22).

Disassembly

To disassemble the backplate (Figure 2-14) the backplate is left on the receiver which will act as a fixture. The adjusting screw is loosened by depressing and holding the adjusting screw plunger with a small drift, and backing out the screw part way, using the combination wrench (Figure 2-23). The backplate is first removed and then the adjusting screw, with care being taken not to lose the plunger and spring. The washer springs and buffer plate can then be pushed out to the rear.

Caution: Plunger must be disengaged before attempting to turn screw.

Assembly

The latch-lock spring is placed in the open end of the latch lock, and the lock inserted (spring leading and center notch down) into its transverse tunnel in the backplate from the left side so that the spring-stop slots align with the vertical stop hole in the backplate. (Lock can be assembled from either side.)

The lock is held in position, and the spring stop inserted into its hole in the bottom of the backplate until it abuts the spring in the lock. Still holding the lock, the spring is compressed with a screw driver or similar tool and the stop is pushed all the way in to retain the spring. The stop should cam over the end coil of the spring and be retained by it. To allow the stop to clear the edge of the hole in the lock, the open end of the lock must protrude slightly from its tunnel.

The latch spring is placed in its seat in the latch and the latch is inserted into the backplate so that the free end of spring seats level, to the rear of the latch lock. The latch then is moved until the pin holes in latch and backplate align and the latch pin is pushed in until flush with sides of the backplate. To facilitate assembly, the latch lock is pushed in until the latch relief cut aligns with latch. When assembled, the latch and lock are operated to make sure that they function properly. When the lock is pushed all the way in, it should be possible to fully raise the thumb piece of the latch.

The buffer plate is inserted in the tube of the backplate, putting it in from the back with the small diameter forward and projecting from the front of the backplate. The ten

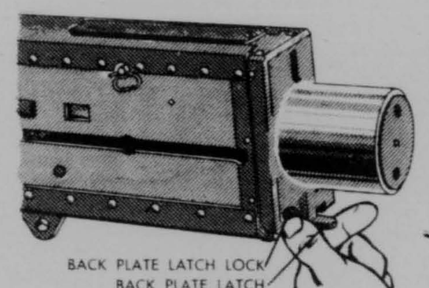

Figure 2–22. Disengaging Lock and Latch Preparatory to Removing Backplate.

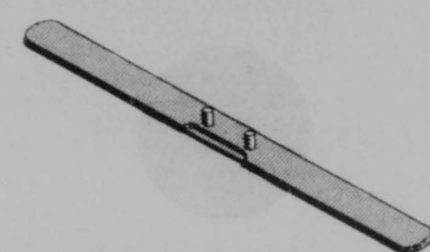

Figure 2–23. Combination Wrench, Cal. .50.

cup-shaped washer springs are inserted in pairs so that the cupped faces of each pair are facing (Figure 2-14). The adjusting screw is started and the plunger and spring inserted. The plunger and spring are depressed to allow the plunger to enter the tube, and the adjusting screw is tightened by hand, the plunger being depressed when necessary. After the adjusting screw is run up by hand it should be tightened a half to a full turn, using the combination wrench (Figure 2-23), as in disassembly, until the plunger snaps into one of the two slots in the tube to lock the screw in place. This gives an approximate torque of from forty to seventy foot-pounds. Subsequent tightening after firing is unnecessary.

Caution: The plunger must be disengaged from the slot in the buffer tube before an attempt is made to turn the adjusting screw.

Installation

The backplate is started into its grooves in the rear end of the receiver side plates. The backplate latch lock is pushed in, the latch is lifted, and the backplate assembly pushed all the way down. The latch is released and then locked. The latch must be fully engaged and the lock springs out to hold it in engagement.

2. BOLT GROUP

Removal

The backplate group is removed. The driving spring rod with springs assembly is removed by pressing forward and away from the right sideplate to disengage the retaining pin from its hole in the plate (Figure 2-25) and withdrawing assembly from the bolt. Care must be taken not to bend the rod while performing this operation. The bolt is pulled to the rear until the bolt stud is in line with the enlarged assembly hole in the center of the slot in the sideplate. The bolt stud is removed by pulling it out to the side. (See Figure 2-26.) The bolt may then be removed by sliding it to the rear.

Disassembly (Figure 2-15)

The extractor assembly is removed by rotating it upward to a vertical position (Figure 2-27) and pulling it out from the bolt. When necessary, the ejector should be removed by depressing the spring-loaded ejector-pin retainer with a small drift inserted in the retainer hole in the extractor, and pushing out the ejector pin. Care should be taken that the ejector and spring do not fly out when the pin

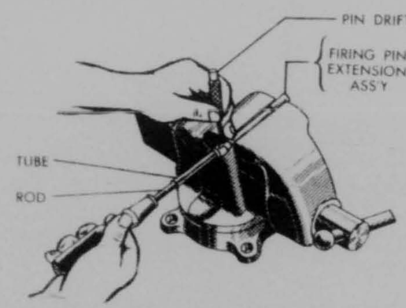

Figure 2–24. Using Firing Pin Spring Removing Tool 41-T-03098-000 (B243646).

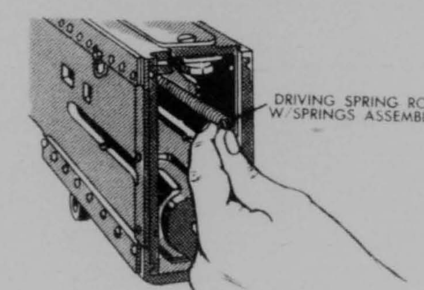

Figure 2–25. Removing Driving Spring Rod w/Springs Assembly.

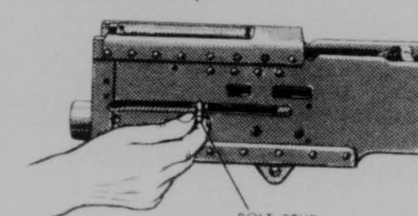

Figure 2–26. Removing Bolt Stud.

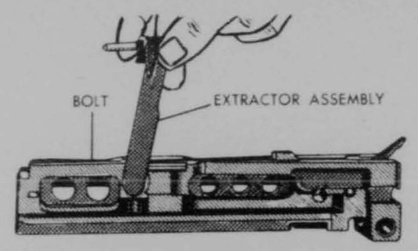

Figure 2–27. Removing Extractor Assembly from Bolt.

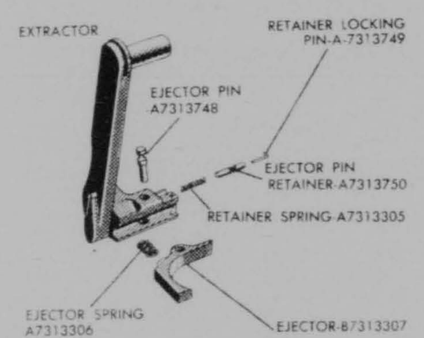

Figure 2–28. Extractor Assembly—Exploded View.

is removed. The retainer is locked in place and should not be removed. Disassembled extractor assembly is shown in Figure 2-28.

The cocking lever is rotated fully backward and the firing pin released by pushing in on the sear. The cocking-lever pin is pushed out and the cocking lever lifted out of the bolt.

Caution: No attempt should be made to release the firing pin with the cocking lever forward, as it will spring back forcibly and may cause serious injury.

The sear is pressed down, the sear-slide stop pin withdrawn from the bolt (Figure 2-29), and the sear slide removed.

Using the thin end of the cocking lever, the flat lock of the firing-pin spring-stop assembly is swung laterally out of its seating groove in the bolt (Figure 2-30), the pin is pushed upon from the under side, and the assembly withdrawn from the bolt.

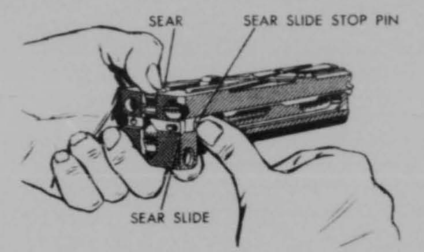

Figure 2–29. Removing Sear Slide Stop Pin.

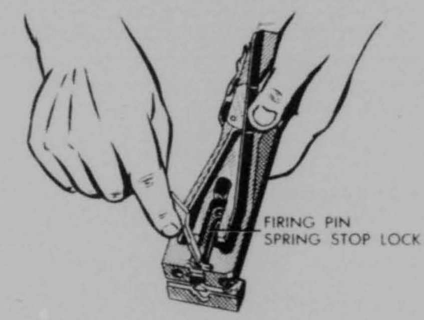

Figure 2–30. Disengaging Firing Pin Spring Stop Lock.

The sear is removed by pulling it up and out of the bolt, and the sear spring is removed.

The front end of the bolt is elevated and the firing-pin extension and firing pin allowed to slide out. The firing pin then is disengaged from the extension by sliding it laterally from the engagement groove in the extension.

The firing pin extension assembly (Figure 2-31) should not be disassembled unless necessary for cleaning or inspection of parts. To disassemble, the firing-pin spring-removing tool is used. If the tool is not available, the firing-pin spring-stop pin is driven out and the spring removed. Care should be taken to prevent the spring from flying out during the operation. To use the firing-pin spring-removing tool, the firing-pin extension assembly is clamped lightly but firmly in a vise. The head of the tool tube is engaged with the end of the extension, so that the slot in the rod straddles the pin in the extension. The rod is pressed in

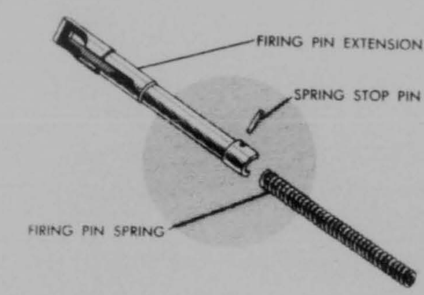

Figure 2–31. Firing Pin Extension Assembly—Exploded View.

to compress the spring, the stop pin is pushed out, and, holding tube against extension, rod is allowed to move slowly rearward in the tube, and spring to expand into the tube. (Figure 2-24)

The bolt switch is removed by depressing the spring-loaded bolt switch stud with a drift and, using the cocking lever as a tool (Figure 2-32), rotating the switch 90 degrees to disengage the interlocking tongue on the under side. The bolt switch is lifted out of the bolt and the bolt switch stud and spring removed from their seat in the bolt.

The cocking-lever stop, if necessary, is removed by prying it toward the rear from the lower left side of the bolt. A small drift is inserted through the hole for the firing-pin spring-stop assembly and the bottom of the stop is pressed down to remove it from its seat, and withdrawn from the top of the bolt.

Assembly (Figure 2-15)

The cocking-lever stop assembly is inserted into the cocking-lever slot in the top of the bolt so that the curved end is facing the front of the bolt (Figure 2-33). The stop then is pushed forward and downward against the end of the slot. Care should be taken that the stop does not interfere with proper seating of the firing-pin spring-stop assembly. The rear end of the cocking-lever stop should be flush with the bottom of the recess in the bolt.

The bolt-switch stud spring is inserted in the bolt-switch stud hole and the bolt-switch

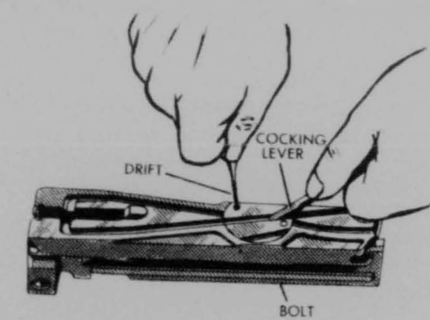

Figure 2–32. Repositioning Bolt Switch, Using Cocking Lever as Tool.

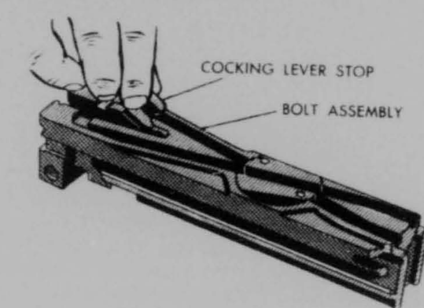

Figure 2–33. Inserting Cocking Lever Stop Into Bolt.

stud is inserted with the small diameter up.

The tongue on the bottom of the bolt switch is aligned with the groove in the bolt and insert switch. The bolt-switch stud is depressed and, using the cocking lever as a tool, the switch is rotated so that the groove marked "L" is continuous if left-hand feed is desired. ("R" for right-hand.) The bolt switch must be retained in position by the engagement of the bolt switch stud.

If the firing pin spring has been removed from the firing pin extension, the spring should be replaced and, after compressing it, secured in place by inserting the firing-pin spring-stop pin. To use the firing-pin spring-removing tool (Figure 2-27) the rod is retracted in the tube of the tool. One end of the spring is placed in the tube and the other in the firing-pin extension, the head of the tube being held over the end of the extension with the slot of the rod in position to straddle the pin holes in the extension. The spring is then compressed into the extension with the rod (Figure 2-24). The stop pin is then inserted, flush with the extension on both sides.

The firing pin and firing-pin extension assembly are engaged and inserted in the tunnel of the bolt with the notch at the rear of the firing-pin extension down. The extension is pushed all the way forward so that the tip of the firing pin protrudes from the face of the bolt.

The sear is pressed down on the spring, so that the spring is seated level on the sear, with the lug on the bottom of the sear inside the coils of the spring. The sear and sear spring are inserted into the bolt, so that the sear spring fits squarely in its seat in the rear bottom of the bolt, and so that the sear is in the vertical grooves in the rear of the bolt, with the wedge-shaped lug facing outward and pointing upward.

The sear slide is inserted into its lateral guideway in the rear end of the bolt with the pointed end leading so that the sloping cam abuts the cam lug on the sear. Then, the sear is depressed slightly and the slide pushed toward the sear lug until the elongated slot in the slide aligns with the sear-slide stop-pin hole in the bolt. The sear slide is retained in position by inserting the sear-slide stop-pin through its hole in the bolt and the slot in the slide. The stop pin should be inserted from the front so that its head faces toward the front of the bolt, and the flat side towards bolt.

Note: The square end of the side must be on the side from which the weapon is to be fired.

The firing-pin spring-stop assembly is inserted in the slot on top of the bolt. Using the wedge-shaped end of the cocking lever as a tool, the flat lock of the stop is swung into its groove in the left side of the slot. The pin of the stop assembly must lie behind the firing-pin spring and not between the coils, when assembled.

The cocking lever (Figure 2-34) is inserted into the slot in the top of the bolt with the rounded nose on the lower end of the lever to

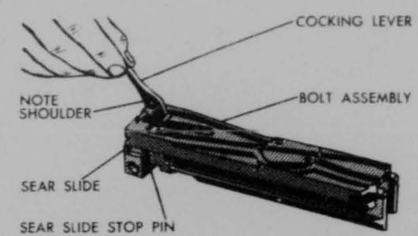

Figure 2—34. Inserting Cocking Lever Into Bolt.

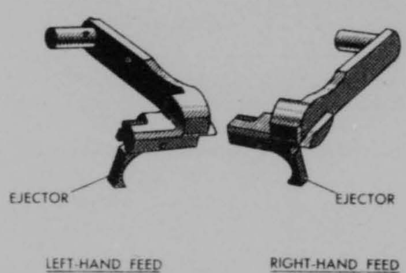

Figure 2—35. Extractor Assembly with Ejector Assembled for Left-Hand and Right-Hand Feed—Front View.

the rear and the shoulder on the side of the lever to the right; the cocking lever pin is then inserted. The head of the cocking lever pin retains the sear-slide stop pin in position; therefore, the cocking lever pin must be inserted from the side to which the sear slide is assembled.

The cocking lever is pushed all the way forward and returned fully to its rear position, and the sear slide is pushed down. A sharp metallic sound heard when the firing pin is released indicates that the firing-pin spring and other components are in good working order. The cocking lever again is pushed all the way forward for proper preparation of the bolt before assembly in the gun.

If the gun is to be assembled for left-hand feed the ejector should be assembled with the claw to the right side of the extractor (Figure 2-35) and, if assembled for right-hand feed, the ejector should be assembled with the claw to the left side of the extractor, when viewed

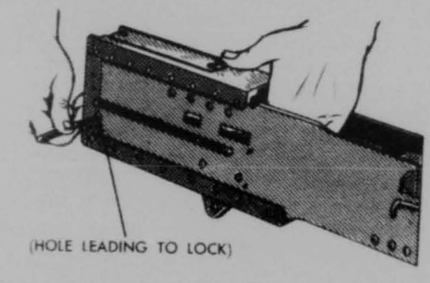

Figure 2—36. Disengaging Barrel Buffer Body Spring Lock.

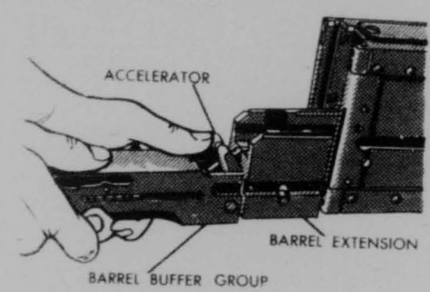

Figure 2—37. Removing Barrel Buffer Group.

from the rear. The ejector spring should always be assembled so that it is on the same side of the ejector pin as the ejector claw. Assembly is as follows:

The ejector is assembled to the extractor by inserting the ejector spring into its seating recess in the extractor and then positioning the ejector, over the spring, in its working slot.

The pin hole in the ejector is aligned with the pin hole in the extractor and the ejector pin is inserted from the rear until it abuts the retainer in the extractor. (The head of the pin must be seated in its countersink in the extractor when fully assembled.) The spring-loaded retainer is pressed in with a drift pin inserted in the retainer hole in the extractor, until the ejector pin is fully seated; the retainer then is released to lock the pin in position. The pin must be fully seated and locked. The spring action of the ejector then is checked.

With the extractor assembly in a vertical position, the pivot is inserted into the bolt as shown in Figure 2-27. As the extractor assembly is rotated forward, the flange on the bottom of the extractor must engage behind the shoulder on the bolt, thus locking it in position. The assembly should not be forced.

Installation

The barrel and barrel extension are pushed far enough to the rear so that the breech lock does not interfere with the entrance of the bolt. With the cocking lever rotated fully forward, the bolt group is inserted into the receiver, and engaged with its ways in the barrel extension. It then is pushed forward until the hole for the bolt stud is in line with the enlarged opening in the center of the slot in the side plate, the bolt stud inserted. Care should be taken when inserting the bolt so as not to trip the accelerator forward. The tip of the cocking lever must be under the top-plate bracket before pushing the bolt forward. The front end of the bolt should be lifted over the tips of the accelerator for easy assembly. The driving-spring rod with springs assembly is inserted into its hold in the bolt and the bolt pushed completely forward. The driving-spring-rod assembly is moved forward, engaging the driving-spring-rod retaining pin in its retaining slot in the right side plate, the head of the rod being pressed flat against the side plate.

Caution: The driving-spring rod with springs assembly must not be used as a lever or guide for the bolt when inserting the bolt in the receiver as this may bend the rod. The rod must be straight and the outer driving spring must not rub excessively or bind in the bolt hole.

The backplate group is installed, with the head of the driving spring rod flat against the side plate and the pin fully engaged in the hole, so that head will seat in the backplate groove.

3. BARREL-BUFFER GROUP

Removal

The backplate group and bolt group are removed.

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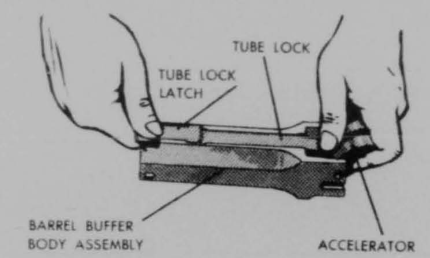

Figure 2—38. Removing Barrel Buffer Tube Lock Assembly.

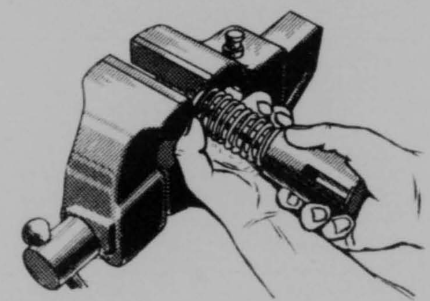

Figure 2—39. Using Vise to Remove Buffer Spring.

A drift pin is inserted in the hole near the rear of the right side plate (Figure 2-36) and the barrel-buffer-body spring lock depressed. At the same time, the barrel, barrel extension, and barrel buffer group are moved to the rear. As the barrel-buffer group emerges from the rear of the receiver it is disconnected from the barrel extension by pushing forward on the tips of the accelerator, as shown in Figure 2-37.

Then, if necessary, the barrel extension and barrel are withdrawn together.

Disassembly (Figures 2-16 and 2-17)

The barrel-buffer assembly is pushed out of the rear end of the barrel-buffer body by pressing on the end of the piston rod with the index finger.

The body is turned over and placed upside down on a bench. With a screw driver or other suitable tool, the rear end of the tube lock latch is raised out of its locking recess in the body (Figure 2-38). (A drift pin, inserted through the hole in the body under the latch, can be used to raise the latch.) With the latch thus disengaged, the tips of the accelerator are elevated and rotated slightly rearward, to move the latch out of its recess, at the same time pressing downward on the forward end of the tube lock, as shown in Figure 2-39. As the accelerator is rotated farther rearward, the tube lock assembly will be pushed out of its recess in the body. The pressure of the hand on the forward end of the lock will keep it from springing out suddenly.

The barrel-buffer-body spring lock is staked in position and should not be removed unless necessary. (It is removed by driving it out to the rear.)

With a drift pin the accelerator pin is pushed out and the accelerator removed. Figure 2-16 shows the barrel-buffer-body group with parts removed.

If a vise is available, the jaws are set about $1\frac{1}{8}$ inches apart; then, holding the barrel buffer firmly in both hands, the edges of the buffer spring guide are placed against the separated jaws of the vise (Figure 2-39). The barrel buffer tube is pressed forward to compress the buffer spring; then the buffer is given a one-quarter turn in either direction to align the piston-rod pin with the slots in the spring guide. The pressure on the tube is released slowly and the spring guide and spring removed. If no vise or other suitable support for the spring guide is available, it is possible to perform the operation as indicated in Figure 2-40.

Assembly (Figures 2-16 and 2-17)

The piston group is inserted into the barrel-buffer tube assembly. The buffer-tube cap is assembled over the piston-rod assembly and the cap screwed tightly into the buffer-tube assembly. Tube and piston should be clean and lightly lubricated.

The buffer spring is placed over the piston rod, and seated on the tube cap, the flat surface of the spring guide is placed on top of the spring with the guide key in line with the pin on the notched side of the piston rod; the

buffer spring is compressed until the ends of the pin in the piston rod pass through the slots in the guide. The piston rod then is given a one-quarter turn and the pin is allowed to seat in its notches in the guide. When assembled, the guide key must be in line with, and to the right of, the notch in the piston rod when viewed from the rear with the notch cap.

If the barrel-buffer-body spring lock has been removed, it should be forced fully into its undercut groove in the side of the barrel-buffer body with the staking notch out and leading, and body is staked into the notch.

With the barrel-buffer body bottom side up, the tube-lock assembly is positioned over the groove in the bottom of the body with the bowed side away from the body. With the flanges of the lock-body over the enlarged cut in the groove, the lock-body is depressed into the cut and slipped forward. The tube-lock assembly is pushed forward until the tube-lock latch can be depressed into the circular opening in the tube-lock groove.

The barrel-buffer body is turned top-side up, and the accelerator placed with the tips up and rounded surfaces to the front in position in the front of the body; the accelerator pin then is inserted, taking care that both ends of the pin are flush with the sides of the body.

The barrel-buffer assembly is inserted into the body, from the rear, with the key in the guide engaged in the slot in the right side of the body, and pushed all the way forward. When assembled, the notch in the piston rod should be up, and the tube lock on the body down. The air port in the buffer tube should be down, although it will function in any position.

Installation

If removed, the barrel and barrel extension are inserted into the receiver until the lower projection on the barrel extension contacts the bottom plate. The barrel buffer assembly must be pushed all the way forward in the barrel-buffer body with the notch in the piston rod up (Figure 2-41). The barrel-buffer body is held in the right hand with the index finger holding up the accelerator. With the

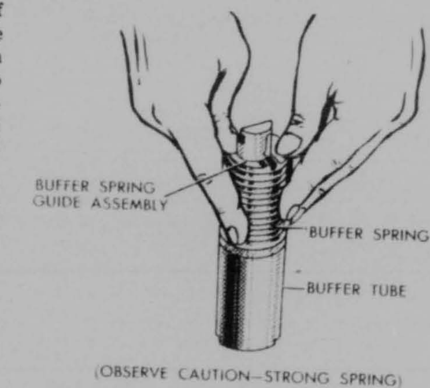

Figure 2—40. Removing Buffer Spring Without Use of View.

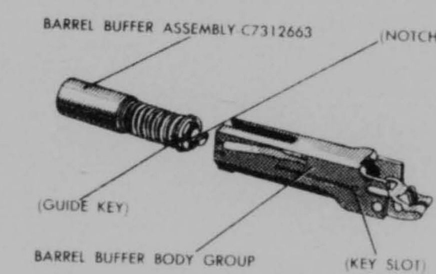

Figure 2—41. Correct Position of Barrel Buffer Assembly for Insertion Into Body.

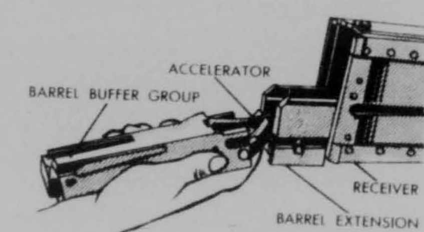

Figure 2—42. Installing Barrel Buffer Group.

rear end of the barrel buffer group slightly depressed, notch in the piston rod is engaged with the barrel-extension shank (Figure 2-42). The tips of the accelerator are engaged with the shoulders of the barrel-extension shank, and the barrel-buffer group pushed

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forward as far as it will go, thus rotating the accelerator upward and to the rear to lock the barrel extension to the barrel buffer group. The tips of the accelerator are pressed down to insure complete locking.

With the groups thus locked together, the rear end is raised until clear of the bottom plate. Then, engaging the breech lock depressors on the side plates with the depressor grooves in the buffer body, the groups are pushed forward until locked in position by the barrel-buffer-body spring lock snapping into its recess in the receiver. If the groups do not move forward readily, a check must be made to assure that the barrel-buffer-tube lock assembly is properly positioned in the bottom of the barrel-buffer body. The barrel-buffer guides (on rear sides of body) must enter the grooves in the receiver. The assembly must not be forced.

The bolt group and backplate group then are installed.

4. BARREL AND BARREL-EXTENSION GROUP

Removal

The following are removed in sequence: backplate group; bolt group; barrel-buffer group; barrel and barrel extension group, by pulling it out through the rear receiver.

Disassembly (Figures 2-18 and 2-19)

The barrel is removed by unscrewing it from the barrel extension.

Note: The barrel locking spring should be slightly raised to minimize wear of notches and the spring when turning the barrel. It should not be forced.

The breech-lock pin is pushed out and the breech lock removed.

The barrel-locking spring is staked in position and should not be removed unless replacement of the spring is necessary. It may be driven out by using a drift pin inserted in the small hole near the rear of the spring.

Assembly (Figures 2-18 and 2-19)

If the barrel-locking spring has been removed, it should be inserted in its recess with

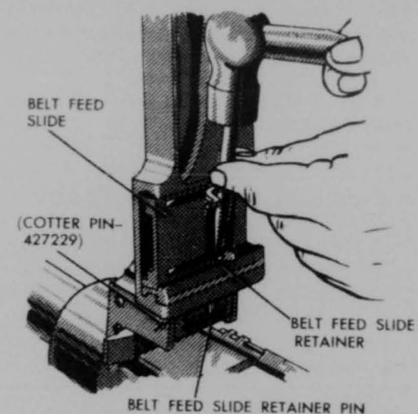

Figure 2—43. Removing Belt Feed Slide Retainer Pin.

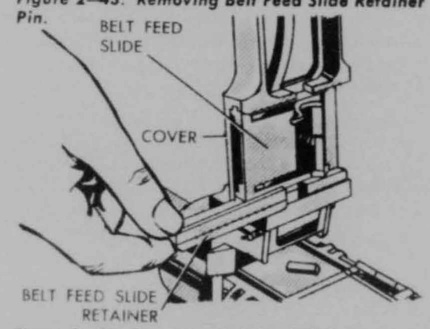

Figure 2—44. Removing Belt Feed Slide Retainer.

the protrusion inside, pushed back as far as it will go, and staked in position.

The breech lock is slipped into its slot in the barrel extension with the beveled face to the front and the notch on top. The pin is inserted so that both ends are flush with the sides of the barrel extension. The spring must be firmly seated in the pin, and retain the pin, when assembled.

The barrel is screwed into the barrel extension, and then back out eight or ten notches to facilitate assembly of the group into the gun.

Note: With the barrel screwed all the way into the extension, the recoiling parts will not go fully into battery, and difficulty may be encountered when installing the barrel, bar-

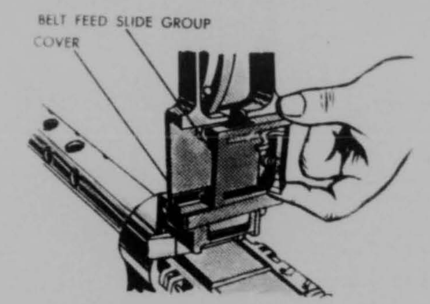

Figure 2—45. Removing Belt Feed Slide Group.

rel extension, and barrel-buffer group. No attempt should be made to operate the gun until the headspace has been adjusted and checked.

Installation

The assembled barrel and barrel-extension group are inserted into the rear end of the receiver until the lower projection on the barrel extension contacts the bottom plate. The barrel-buffer group is assembled to the barrel extension. These parts are then raised to clear the bottom plate, and pushed forward in the receiver until locked in position by the buffer-body spring lock. The bolt group and backplate group are then installed.

5. COVER GROUP

Disassembly (Figures 2-20)

With the cover raised, the belt-feed-slide retainer pin is driven out toward the hinge by inserting a drift in the half round hole appearing in the belt-feed slide retainer (Figure 2-43).

The belt-feed slide retainer is withdrawn from the cover (Figure 2-44) and the belt-feed slide group lifted out of its seat. (Figure 2-45)

The front end of belt-feed lever is aligned with the slot in the cover and the lever lifted off at the stud. Care must be taken so as not to lose the belt-feed lever plunger and spring.

The belt-feed lever plunger and spring are removed from the hole in the lever.

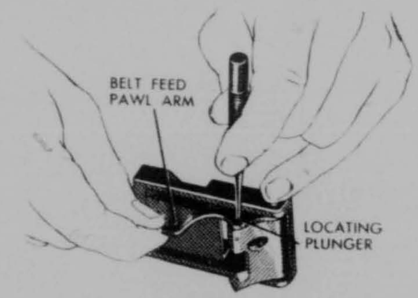

Figure 2—46. Depressing Locating Plunger to Remove Belt Feed Pawl Arm.

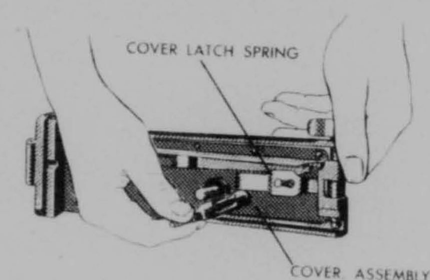

Figure 2—47. Removing Cover Latch Spring.

Using a drift pin, the belt-feed pawl-arm locating plunger (in center of arm) is depressed, and the arm slipped away from the belt-feed pawl pin to disengage it from the groove in the pin (Figure 2-46). The pawl is held down against the spring pressure, the pawl pin is pushed out and the pawl and springs removed from the slide. When it is necessary to remove the belt-feed pawl-arm locating plunger, the locking pin is driven out of the pawl and the plunger and spring removed. Care should be taken to see that the plunger does not fly out.

The end of the cover-latch spring is lifted out of the groove in the cover (Figure 2-47) and this lifted end is turned slightly so that it rests on the cover-extractor spring. The cover-latch spring is compressed by firm pressure of the thumb, and the spring slipped away from the latch and removed.

The cover-extractor spring is held with

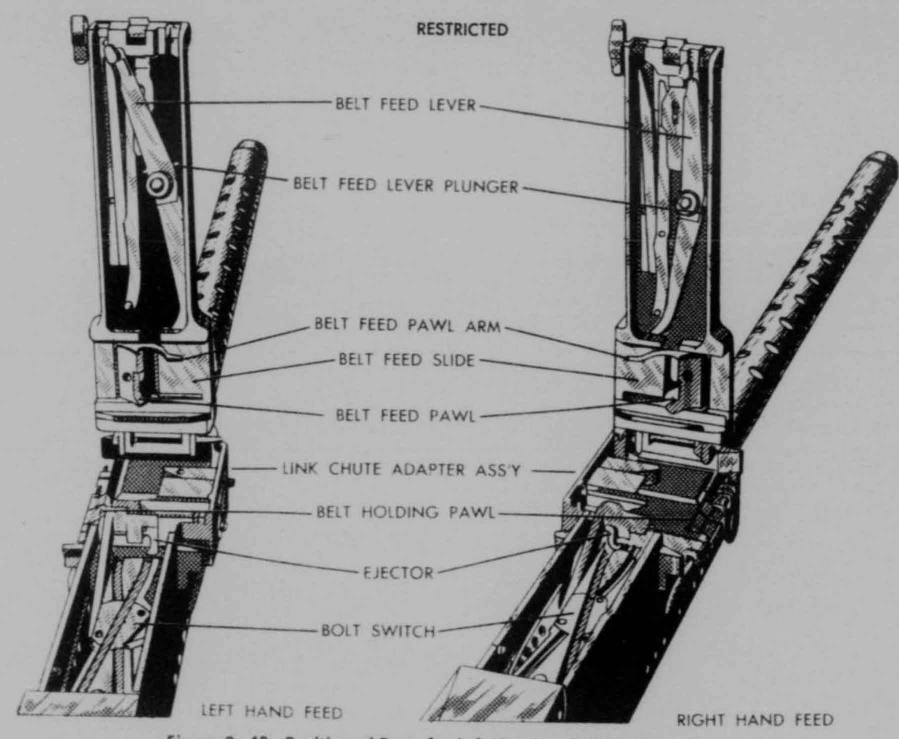

Figure 2–48. Position of Parts for Left-Hand and Right-Hand Feed.

the thumb to keep it from flying out, and the rear end of the spring is pried laterally out of its retention recess in the cover extractor cam. The spring is removed by disengaging it from the holding stud at the opposite end.

To remove the cover latch, the shaft cotter pin and washer are removed, the latch shaft is turned to the latched position, and the shaft is withdrawn from the cover.

Assembly (Figure 2-20)

To assemble the latch to the cover, the latch is placed between the shaft bosses on the under side of the cover with the keyway toward the top of the cover and with the projecting wing of the latch against the under side of the cover; the shaft may be installed from either side but, for convenience, the shaft lever should be on the opposite side from the charger or other bolt-retracting device, to provide clearance. The latch shaft assembly is inserted with the key on the shaft toward the cover. The washer is placed on the shaft and secured by inserting the cotter pin with the head toward the hinged end of the cover. The ends of the pin are bent closely against the shaft to avoid interference when latching the cover.

The cover extractor spring is installed by hooking the slotted end under the extractor-spring stud, with the curved end away from the cover. The spring is held firmly against the stud, the curved end is depressed, and engaged in the retention recess in the cover extractor cam.

The cover latch spring is placed inside the cover with the bent end against the cover and the enlarged hole over the extractor spring stud. The latch end of the spring must ride over the projecting wing of the latch, the spring must be depressed and, at the same time, the spring must slide toward the latch.

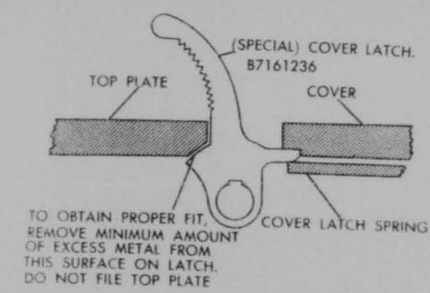

Figure 2–49. Cover and Top Plate with Special Cover Latch in Position—Sectional View.

The bent end of the spring is snapped into the lateral groove in the cover.

The belt-feed lever spring and plunger is placed in the top hole of the belt-feed lever (cover open) for left-hand feed (bottom hole for right-hand feed), as shown in Figure 2-48. The hole in the center of the lever is placed over the belt-feed-lever pivot stud in the cover and the toe of the lever is positioned in the slot in the hinge end of the cover. The lever is pressed down on the stud until seated against the cover, with the plunger bearing on the side of the cover.

If the belt-feed pawl-arm locating plunger and spring have been removed from the pawl, the spring is placed in the plunger hole in the pawl, the plunger is pressed in over the spring (large diameter leading) so that the cut in the plunger and pin hole in the pawl align; the locking pin then is inserted. The plunger must function smoothly when depressed and released, and both ends of locking pin must be below the faces of the pawl.

When assembled, the belt-feed slide group must be seated in the cover with the belt-feed pawl toward the side from which ammunition is to be fed. The feed pawl must be assembled in the slide so that the feed-pawl-arm locating plunger is toward the latch end of the cover when the slide group is seated in the cover. The feed-pawl arm must be assembled to the pawl so that the convex curve of the free end of the arm is away from the cover. This assembly will place the feed-pawl arm to the rear of the pawl, with the curve of the free end pointing down, when the cover is closed. Proper assembly for both left-hand and right-hand feed is shown in Figure 2-48. To assemble the slide group the procedure is as follows:

The small end of the outer (large) belt-feed pawl spring is seated over the spring stud in the slide, and the inner (small) spring is seated inside the outer spring. The pawl then is placed in the slide with a spring seat recess directly opposite the spring stud in the slide, so that the free ends of the springs seat squarely in the spring-seat recess in the pawl; the pawl is pressed down on the springs until the pawl holes in the slide and pawl align. The pawl pin, grooved end leading, is pushed through the slide and pawl, from the side opposite to the arm locating plunger in the pawl.

The flat of pawl arm is pressed down on the arm-locating plunger in the pawl to depress it, and the forked end of the arm is slipped toward the groove in the pawl pin until the fork seats in the groove and the locating plunger snaps through the hole in the arm.

The assembled slide group is placed in its way (groove) in the cover with the pawl end of the slide toward the side from which the gun is to be fed, engaging the end of the belt-feed lever in its seating recess in the slide. The belt feed slide retainer is slipped into its ways in the cover, the pin hole is aligned in the retainer and cover and the belt-feed slide retainer pin inserted from the bottom (cover raised). The slide is operated by moving the feed lever to see that there is no binding. With the cover closed, a check is made to see that the feed pawl is on the side from which ammunition is to be fed, and the pawl arm is to rear of the pawl convex curve of free end pointing down.

Installation

Special Cover Latch. A special cover latch (Figure 2-49) is available for use in some installations. This latch differs from the standard latch in that it has a projecting prong, so that when link jams occur, the operator may open the cover by operating the cover latch itself, without removing his gloves. (The standard latch is operated by turning the cover-latch shaft lever which is difficult to

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reach in some installations without the operator first removing his gloves.)

If this special latch is to be installed in place of the standard latch, a slight amount of fitting may be required. When necessary, excess metal should be removed from the latch at the point shown in Figure 2-49. (No metal should be removed from the top plate.) A minimum amount of metal should be removed, so that looseness does not exceed approximately 0.008 inch. Looseness may be measured by inserting a feeler gauge between the rear of the latch and top plate, with the cover latched. The same fitting should be done, when necessary, to a new, standard latch when assembled.

6. RECEIVER AND BARREL-JACKET GROUP

Disassembly (Figure 2-21)

The belt-holding pawls, sleeve, and springs are removed by withdrawing the belt-holding pawl pin, with care being taken not to lose the springs. If the spring in the end of the pin does not cam down freely, it should be depressed before withdrawing the pin. It should not be forced.

The link-chute adapter assembly is removed by lifting it straight up from the belt-holding pawl pin. If necessary, the pin is withdrawn as explained above.

The cover detent pawl is removed with the spring assembly by pulling the pawl up out of the trunnion block. The spring should not be removed from the pawl. If the trunnion block cover is to be removed for the installation of a sight, it can be detached by driving out the lateral pins.

To remove the (extractor) switch, the cotter pin is pulled from the switch-pivot nut, the nut is unscrewed and the switch and switch spring pulled out.

To remove the breech lock cam the cotter pin is pulled out of the breech-lock cam bolt which protrudes through the bottom plate of the receiver, and the nut is removed. The breech-lock cam bolt and cam are withdrawn from the inside of the receiver.

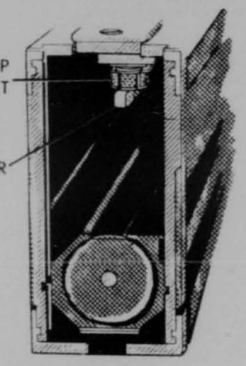

Figure 2–50. Trigger Bar Adjustable Stop Assembly, Assembled in Receiver—Rear View.

Note: The breech-lock cam should not be removed, except for replacement or when cleaning is imperative.

The trigger-bar pin assembly is removed by lifting the lock until it is perpendicular to the side plate and by rotating the pin about 90 degrees. The projection on the pin which forms a key will then pass through the keyhole in the side plate and the pin can be removed by pulling it out from the gun. When the pin is removed, the trigger bar is free. The trigger bar then is removed from inside the receiver.

To remove the trigger-bar adjustable-stop assembly from the rear of the receiver, the retaining screw is removed from the rear of the top plate and the assembly is pulled down off the rear trigger-bar stop which serves as a positioning pin. To disassemble the assembly, the adjusting nut is unscrewed and the spring removed.

The recoil booster is removed by unscrewing the two screws locking the booster to the barrel jacket and unscrewing the booster from the jacket.

When assembled, the trunnion adapter may be removed by pulling the trunnion-block lock, located in the under side of the trunnion block, to the rear and giving it a one-quarter turn so that the projecting cotter pin will hold it out of engagement with the adapter. The adapter then is unscrewed and removed together with the shim. The cotter pin in lock must not become bent or loose, or the lock cannot be retracted or held in the disengaged position.

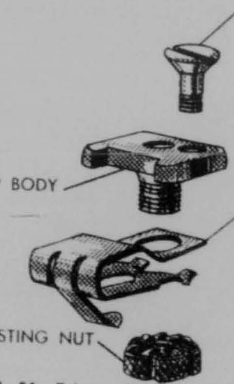

Figure 2–51. Trigger Bar Adjustable Stop Assembly—Exploded View.

The recoil adapter assembly, when used in place of the trunnion adapter, may be removed in a similar manner as described above.

Assembly (Figure 2-21)

The recoil booster is screwed into the barrel jacket until the holes in the jacket and booster are in alignment. It is inserted, tightened, and the two screws staked.

To install the trigger bar adjustable stop assembly (Figures 2-51 and 2-21) the stop body is positioned on the rear trigger-bar stop (pin) and fastened by threading the retaining screw through the top plate cover, top plate, and stop body, and stake screw (Figure 2-50). The adjusting-nut spring is seated in the body with prongs forward and down, and the nut threaded onto the body with notches up. When assembled, the end of the screw must not interfere with level seating of the spring in the body, and the prong of the spring, which cushions the trigger bar, must not be distorted.

The trigger bar is placed with the long end forward and the bowed surface upward, between the top-plate bracket and the bolt-latch bracket, and held up firmly. When positioning, the trigger bar should project approximately $\frac{5}{16}$ inch beyond the rear trigger bar stop. With the trigger bar held in that position, the lock of the trigger bar pin assembly is raised in line with the pin, the pin is inserted through the left side plate with care being taken to match the key on the pin with the keyhole in the side plate. After insertion, the lock is rotated 90 degrees until stopped by the flange of the top plate and the lock is pushed down flat against the side plate.

If the breech-lock cam has been removed or has to be replaced, it should be placed in the receiver with the cam surface up and sloping to the rear. The lower projection of the cam is placed through the hole in the bottom plate and the breech-lock cam bolt is inserted from the top. The castellated nut is screwed on the bolt with the notches (castellations) toward the bottom surface of the bottom plate, and drawn tight. The nearest castellation in the nut is lined with the cotter pin hole in the bolt and the cotter pin inserted. Prongs of the pin are spread and bent snugly around the nut. The head of the cam bolt must not project above the cam.

To install the (extractor) switch, the bent end of the switch spring is first inserted into the small hole in the switch recess in the inner face of the left side plate, with the long end of the spring outside and above the recess. The switch pivot then is started into its hole in the side plate, so that the lug on the switch is above the spring. Then, making sure the lug on the switch rides on top of the spring, the switch is rotated downward and pressed against the side plate until the spring and switch snap into the recess. The nut is threaded onto the projecting pivot and drawn up snugly, but it must not be forced. The nut is loosened slightly if necessary to line up the notches (castellations) in the nut with the hole, in the pivot. The cotter pin is inserted and the prongs bent snugly around the nut to prevent interference. The switch is checked to see that it pivots freely, snaps back into position, and that there is no unnecessary side play. Figure 2-52 shows the switch and spring in assembling position in the receiver.

The cover-detent pawl assembly is inserted spring first into its hole in the trunnion block, and pawl is seated laterally in the block. If the trunnion-block cover has been removed, it should be placed in position and the two pins inserted.

For left-hand feed, the belt-holding pawls

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are placed in position on the left side of the receiver and vice versa. The right-hand and left-hand pawls are placed on the belt-holding pawl sleeve, the springs are seated in the holding-pawl bracket, the assembled pawls and sleeve are placed in position over the springs so that springs seat in pawls and secured with a belt-holding pawl pin. The pin is pushed home until securely locked, and the handle is turned down.

The remaining belt-holding pawl pin is inserted securely in the opposite bracket and the link-chute adapter assembly (Figure 2-53) placed in position on the pin with the curved front stop forward. Figure 2-11 shows the belt-holding pawls and link-chute adapter installed for right-hand feed. The link-chute adapter is always installed on the opposite side of the feedway from the belt-holding pawls. When in position the curved front stop should be forward and the long end of the cartridge guide up (Figure 2-11). Position of the guide can be changed by removing the screws, withdrawing and reversing the guide, and then, replacing the screws tightly. In adapters of recent design there is only one positioning ball in the front stop of the adapter. This ball should be on top when the adapter is installed. To change position of the ball, the positioner assembly containing the ball is pushed out from the side opposite the ball, and then reseated in the opposite side of the stop.

If the trunnion adapter has been removed, it may be installed by disengaging the trunnion-block lock, and then placing the shim in position and screwing on the adapter. If, when the adapter is snugly screwed on, the hole in adapter does not align with the lock, a thicker shim is used. (Shims are numbered according to their thickness.) With shim and adapter aligned, the trunnion-block lock is given one-quarter turn and allowed to seat in the hole in the adapter. The lock must pass through the shim and must be fully seated in the adapter; the cotter pin in the lock must not be bent or broken or the lock may stick, so that it cannot be retracted.

The recoil adapter, when used in place of the trunnion adapter, may be installed in a manner similar to that described above with the exception that no shims are used.

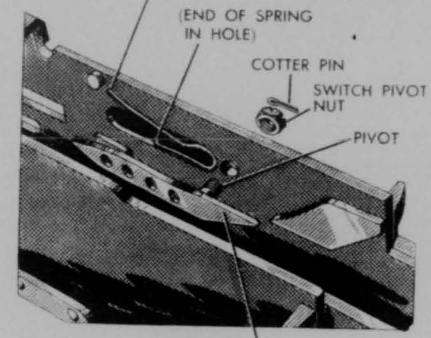

Figure 2–52. (Extractor) Switch and Switch Spring in Assembling Position.

7. CHANGING FEED

In order to change the gun from left-hand feed to right-hand feed, or vice versa, repositioning of parts must be carried out in the bolt group, cover group, and certain parts in the receiver, as shown in Figure 2-48. The following describes, in general terms, the change from left-hand feed to right-hand feed. By reversing the process, the gun may be changed from right-hand feed to left-hand feed (Figure 2-48).

Bolt Group

The bolt group is removed from the gun, the extractor assembly, and the cocking lever from the bolt.

The spring-loaded switch stud is depressed using a drift and, by means of a cocking lever or other tool (Figure 2-32), the switch is rotated until the stud engages the opposite hole. The cam groove in the bolt switch will then line up to make the groove bolt marked "R" (right) continuous. The cocking lever is then replaced in the bolt.

Note: When assembled for right-hand feed, the enlarged portion of the bolt switch is toward the rear of the bolt.

The ejector is removed from the extractor and reversed so that the claw is on the left side when viewed from the rear (Figure

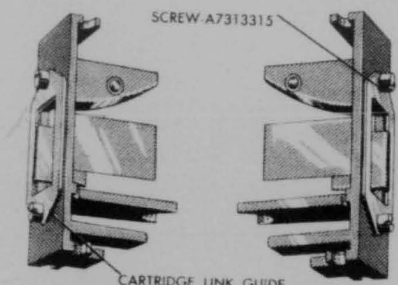

Figure 2–53. Link Chute Adapter Assembly (C7313314) Assembled for Right-Hand and Left –Feed Top View.

2-35). The ejector spring is reversed so that it is on the same side of the ejector pin as the ejector claw.

The ejector is reassembled, the extractor assembly is assembled to the bolt, and the bolt group replaced in the receiver.

Note: The square end of the sear slide must be on the side from which the weapon is to be fired. If necessary, the sear slide, sear slide stop pin, and cocking lever pin should be repositioned on the opposite side of the bolt.

Cover Group

With the cover open, the belt-feed slide retainer and the belt-feed slide group is removed from the cover.

The belt-feed lever is removed and the belt-feed lever plunger and spring transferred from the upper hole (cover open) in the belt-feed lever to the lower hole.

The belt-feed lever is reinstalled, the belt-feed slide group is reversed and replaced in its groove in the cover with the pawl end of the slide toward the right. The belt-feed slide retainer is then reinstalled.

The belt-feed pawl-arm locating plunger is depressed in the pawl (Figure 2-46) and is withdrawn.

The slide is pushed to the right and held so that the belt-feed pawl pin can be pushed out of place; the belt-feed pawl pin, belt-feed pawl, and springs are removed from the slide. Care should be taken not to lose the springs.

The belt-feed pawl is repositioned by turning it over so that the spring seat in the opposite side aligns with the stud for the belt-feed pawl springs.

The belt-feed pawl and springs are reassembled to the belt-feed slide and secured by inserting the pin from the bottom, with grooved end leading.

The belt-feed pawl arm is reversed, the locating plunger is depressed in the pawl, and the arm slipped over it so that the notch in the end of the arm engages the groove in the pawl pin and the plunger seats in the hole in the arm.

Receiver Group

The link-chute adapter is lifted from its belt-holding pawl pin, and the pin is removed from the bracket on the side plate.

The remaining belt-holding pawl pin is removed from the other bracket and the belt-holding pawls, sleeve, and springs removed.

The belt-holding pawls, sleeve, and springs are assembled to the right-hand side of the receiver.

The link-chute adapter assembly is assembled for right-hand feed and installed on the left side of the receiver, after having installed the remaining belt-holding pawl pin.

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SECTION III—CYCLIC FUNCTIONING OF THE GUN

1. GENERAL

Cyclic functioning of the aircraft machine gun cal. .50, M3 is identical with that of the Browning aircraft machine gun, cal. .50, M2. The barrel buffer of the gun M3 takes the place of, and functions in the same general manner as, the oil buffer of the gun M2. In the barrel buffer of the gun M3 the washer springs and air compression feature take the place of the oil and valve system of the oil buffer of the gun M2.

The gun M3 may be fired by means of a top-plate solenoid acting upon the sear through the medium of a trigger bar, or by a side-plate solenoid, trigger motor or other device acting upon the sear through the medium of the sear slide. In any case, the functional operation of the gun is the same. For clarity, the illustrations in this section show the sear operated by a trigger bar.

Each time a cartridge is fired, the mechanical action within the gun involves many parts moving simultaneously or in their proper order. The action of these parts, and their relationship one to the other, can be explained more clearly if each cycle of operation is divided into various phases. These phases will be explained in the following paragraphs of this section in the order indicated in d below. Familiarity with the construction of the gun and function of its component parts and groups, as explained in sections pertaining to the groups, is necessary to a thorough understanding of the cyclic functioning of the gun as a whole. A clear understanding of the following explanations may be gained by hand operation of a gun, using dummy ammunition. Figure 2-54 shows a cutaway view of the unloaded gun with the recoiling parts in the forward or "battery" position.

For convenience and clarity, cycles of operation are divided into the following phases and explained in the order indicated.

Firing

Automatic Firing

Recoiling

Feeding

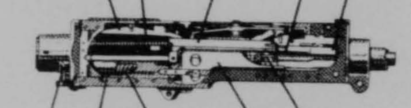

Figure 2–54. Receiver Section of Gun—Cutaway View.

Counterrecoiling

Extracting

Ejecting

Cocking

2. FIRING

When the gun has been loaded and the firing pin has been cocked, the firing pin and extension engages the sear. The firing mechanism of the gun is made ready to be fired by disengaging the sear from the firing-pin extension. In this case, the trigger bar will be rotated on its pin to depress the sear by a linkage with the top-plate solenoid when operated.

If the gun is fired by means of a top-plate solenoid and trigger bar, the firing-pin extension and firing pin is released by actuating the solenoid. When the plunger of the top-plate solenoid acts on an actuating lever assembled to the trigger-bar pin assembly, the lever presses down on the forward end of the trigger bar, causing the front end of the trigger bar to press down on the top of the sear.

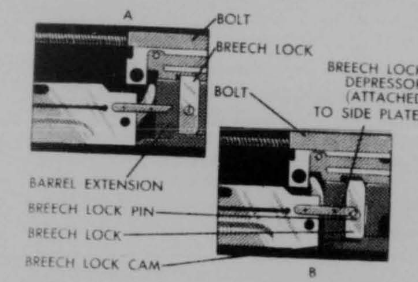

Figure 2–55. Breech Lock Locked "A" and Unlocking "B".

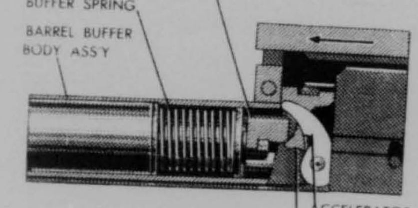

Figure 2–56. Buffer Spring Compressed and Held By Locked Barrel Extension—Bolt Still Moving Rearward.

The sear is forced downward until the notch in the sear is disengaged from the shoulder of the firing-pin extension. The firing pin and firing-pin extension are driven forward by the firing-pin spring to fire the cartridge.

If the gun is fired by means of a side-plate solenoid, the trigger motor or other device, when actuated, is forced against the sear slide. The sear slide, moving laterally, cams down the sear and the firing pin is released to fire the cartridge as explained above.

3. RECOILING

The complete cycle of the recoiling parts of the gun, which takes place as each cartridge is fired, consists of the recoil movement when certain parts move rearward, and the counter-recoil movement when the same parts move forward. At the instant the first shot is fired, the barrel, barrel extension, and the bolt, known as the "recoiling parts," are in the fully forward or "battery" position in the gun.

At this time the bolt is locked to the barrel extension and held securely against the rear of the cartridge in the chamber of the barrel by the breech lock, which extends up from the barrel extension into a notch in the under side of the bolt. The breech lock is held up by the breech-lock cam upon which it rests. "A" (Figure 2-55) figure shows bolt locked.

After the cartridge explodes and as the bullet travels out of the barrel, the force of recoil drives the recoiling parts rearward. During the first $5/8$ inch of rearward travel, the breech lock is moved off the breech-lock cam step. This permits the breech lock to be forced down out of the notch in the bolt by the breech-lock depressors engaging the breech-lock pin. This unlocks the bolt from the barrel extension. "B" (Figure 2-55) shows beginning of unlocking action.

As the recoiling parts move toward the rear, the barrel extension bears against the accelerator and rotates it rearward. The tips of the accelerator strike the lower projection on the bolt and accelerate the bolt to the rear.

The barrel and barrel extension have a total rearward travel of $1\frac{1}{8}$ inches at which time they are completely stopped by the barrel-buffer body.

During this recoil, the buffer spring in the barrel buffer is compressed by the rearward movement of the barrel extension, transmitted through the barrel extension shank to the buffer piston rod with which it is engaged. The spring is held in the compressed position by the barrel extension (Figure 2-56), locked by the claws of the accelerator which are moved against the shoulders of the barrel extension shank. The buffer spring assists the barrel-buffer piston in bringing the barrel and barrel extension to rest during the recoil movement.

During recoil, the barrel-buffer piston is forced from the forward end of the barrel-buffer tube to the rear, compressing the air confined in the tube to the rear of the piston. The piston starts rearward rapidly due to an air port or hole in the wall of the barrel-buffer tube within which it moves. The port allows

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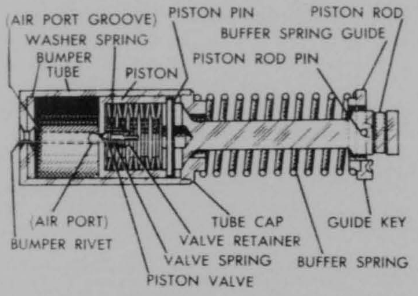

Figure 2—57. Barrel Buffer Assembly with Piston in Forward Position—Sectional View.

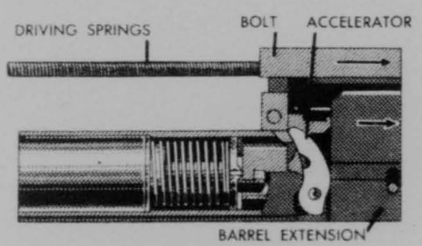

Figure 2—58. Bolt Striking Accelerator to Release Barrel Extension and Buffer Spring.

some air in the tube to escape quickly-at the start of the rearward movement of the piston. As the piston moves beyond the port, the remaining air in the tube is gradually compressed, thus forming a cushion. As the compression increases, the compressed air escapes into the piston through a spring-operated relief valve in its rear end. The escaped air then passes through the piston and out of the buffer tube through the enlarged rod hole in the tube cap. The valve regulates the flow of escaping air so that the rearward movement of the barrel extension and barrel is decelerated gradually. The opening of the relief valve is controlled by a spiral spring seated in a retainer in the piston. The retainer is held in place by ten cupped washer springs assembled in the piston, which bear upon the retainer and the rear face of the piston rod and act as a cushion for the rod at the end of the rearward movement. No terminal shock is transmitted to the buffer piston pin or piston rod due to the elongation of the pin hole in the rod. Figure 2-57 shows construction of the barrel-buffer assembly.

The bolt travels rearward for a distance of 7.2 inches plus compression of the buffer pile in the backplate. During this travel, the driving springs are compressed. The rearward movement of the bolt is finally stopped as the bolt strikes the buffer plate in the backplate. Thus, part of the recoil energy of the bolt is stored in the driving springs, and part is absorbed and stored by the cupped washer springs upon which the buffer plate bears, in the backplate tube. Any remaining recoil energy is transmitted to the recoil adapter on the gun or on the gun mountings and therefore the recoil mechanisms.

4. COUNTERRECOILING

After completion of the recoil movement, the bolt is forced forward by the energy stored in the driving springs and the compressed backplate buffer washer springs. When the bolt has moved forward about 5¾ inches, the projection on the bottom of the bolt strikes the tips of the accelerator and rotates it forward (Figure 2-58). This rotation moves the claws of the accelerator away from the shoulders of the barrel extension shank. This releases the (barrel) buffer spring. The energy stored in the spring, supplemented by the counterrecoil energy of the bolt transmitted through the accelerator, forces the barrel and barrel extension forward.

No restriction to the forward motion of the barrel and barrel extension is desired: therefore, on the forward movement the air ahead of the piston in the barrel-buffer tube is allowed to escape through the enlarged hole in the tube cap through which the piston rod passes. As the piston nears its forward position, the air port in the tube is uncovered, allowing air to enter the rear end of the tube and relieve the vacuum created by the forward movement of the piston.

Note: Air is permitted to leave and enter the port in the barrel-buffer tube through a longitudinal groove in the tube. This groove extends from the port to the rear end of the tube.

As the barrel extension moves forward, the breech lock engages the sloping ramp of the breech lock cam and is forced upward. The bolt, which has been continuing its forward motion since striking the accelerator, has at this instant reached a position where the notch in the under side of the bolt is directly above the breech lock, permitting the breech lock to enter the notch and engage the bolt. Thus the bolt is locked to the barrel extension just before the recoiling parts reach the firing position.

5. COCKING

The act of cocking the gun begins as the bolt starts to recoil immediately after firing. As the bolt moves rearward, the tip of the cocking lever, which is in the V-slot in the top plate bracket, is forced forward. Since the cocking lever pivots on the cocking lever pin, the lower end, which engages in a slot in the firing-pin extension, is forced rearward, thereby pulling the firing-pin extension and firing pin rearward and compressing the firing-pin spring against the pin of the firing-pin spring stop. The shoulder on the rear end of the firing-pin extension forces the sear downward, against its spring, and continues to travel rearward until slightly beyond the front face of the notch in the sear. The sear is then immediately forced upward by the sear spring to a position where it will engage the shoulder on the firing-pin extension when it starts moving forward again. Figure 2-59 shows position of the bolt and its components during the rearward movement.

During the forward movement of the bolt, in counterrecoil, the tip of the cocking lever again enters the V-slot in the top-plate bracket and is forced rearward. This action swings the lower end of the cocking lever forward out of engagement with the firing-pin extension which moves forward so that its shoulder is engaged and held by the sear. The cocking lever acts as a safety device to prevent the firing-pin extension and firing-pin, if released prematurely, from moving fully forward to fire the cartridge before the bolt has gone forward sufficiently for the breech lock to be engaged, and thus lock the bolt to the barrel extension. When the recoiling parts

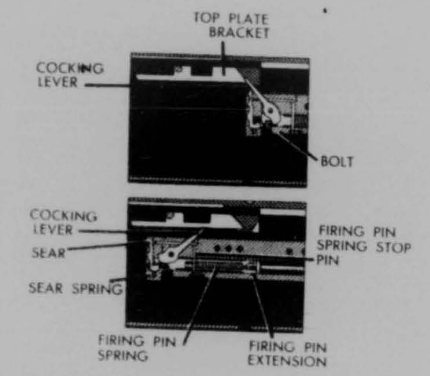

Figure 2—59. Action of Cocking Lever During Recoil.

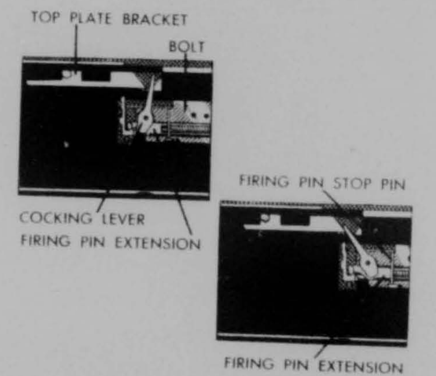

Figure 2—60. Action of Cocking Lever During Counterrecoil.

are approximately .116 inch to .120 inch from the fully forward "battery" position, depending on the "timing" of the gun, the gun is ready to fire. If, at this instant, the sear is not depressed, the recoiling parts will assume their fully forward "battery" position and the gun ceases to fire. Figure 2-60 shows the bolt and its components during the forward movement.

Automatic Firing

For automatic firing by means of a top-plate solenoid, the solenoid must be operated

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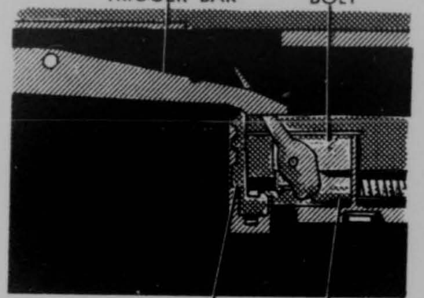

Figure 2–61. Automatic Firing—Sear Depressed by Held-Down Trigger Bar at End of Counterrecoil Movement.

so that the lever moves the end of the trigger bar downward and is then held in that position. The sear is depressed as its top is carried against the cam surface of the depressed trigger bar by the forward movement of the bolt near the end of the counterrecoil movement (Figure 2-61). The depression of the sear releases the firing-pin extension and the firing pin, thus automatically firing the next cartridge. The gun fires automatically as long as the solenoid action is maintained and until the ammunition supply is exhausted.

Automatic firing by means of a side-plate solenoid is accomplished in a similar manner. As the bolt nears the end of its counterrecoil movement, the end of the sear slide is engaged by the cam surface of the projecting solenoid plunger and is forced sideways. This lateral movement of the sear slide cams the sear downward, thus releasing the firing-pin extension and firing pin to fire the gun as outlined above.

Feeding

The belt-feed mechanism is actuated by the bolt. When the bolt is in the forward position the belt feed side is entirely within the gun. (See "A", Figure 2-62.) A lug on the rear end of the belt-feed lever rides in one of the two diagonal cam grooves in the top of the bolt. The forward end of the belt-feed lever engages in a slot in the belt-feed slide to which the belt-feed pawl and belt-feed pawl arm are attached.

When the bolt is moved rearward, the belt-feed lever is pivoted about the belt-feed lever pivot stud, and the forward end of the lever moves the slide out of the side of the gun over the ammunition belt, which is held in the gun by the belt-holding pawl.

When the bolt moves forward, the belt lever is again pivoted and moves the belt-feed slide into the gun. The belt-feed pawl attached to the slide engages a round of the ammunition belt and pulls the belt into the gun. By the time the bolt has reached its forward position, the belt-feed pawl has pulled a cartridge into the feedway to a central point directly above the chamber of the barrel and against the cartridge stops of the link chute adapter. At this position, the hook of the extractor is in engagement with the rim of the cartridge case. The belt-holding pawl has assumed a raised position behind a link of the ammunition belt to prevent the belt from falling out of the gun. (See "A", Figure 2-62.) Feeding during recoil and counterrecoil is as follows:

As the bolt recoils, the extractor withdraws the centered cartridge from the belt, and the belt-feed slide is moved out over the belt, and the belt-feed pawl pivots to ride over the link holding the next cartridge in the belt. (See "B", Figure 2-62).

At the end of the recoil movement, the travel of the belt-feed slide is sufficient to permit the belt-feed pawl to snap down behind the link holding the next cartridge in order to pull the belt into the gun. (See "C", Figure 2-62. The centered cartridge in this figure has been extracted from the belt.)

As the bolt moves forward in counterrecoil, the belt is pulled into the gun by the belt-feed pawl. The belt-holding pawl is forced downward as the belt is pulled over it. (See "D", Figure 2-26.) As the cartridge is positioned in the feedway, the belt-holding pawl snaps up behind the link holding the next cartridge to keep the belt from falling out of the gun. (See "A", Figure 2-62).

Note: If the cartridge in the feedway awaiting extraction from the belt fails to be

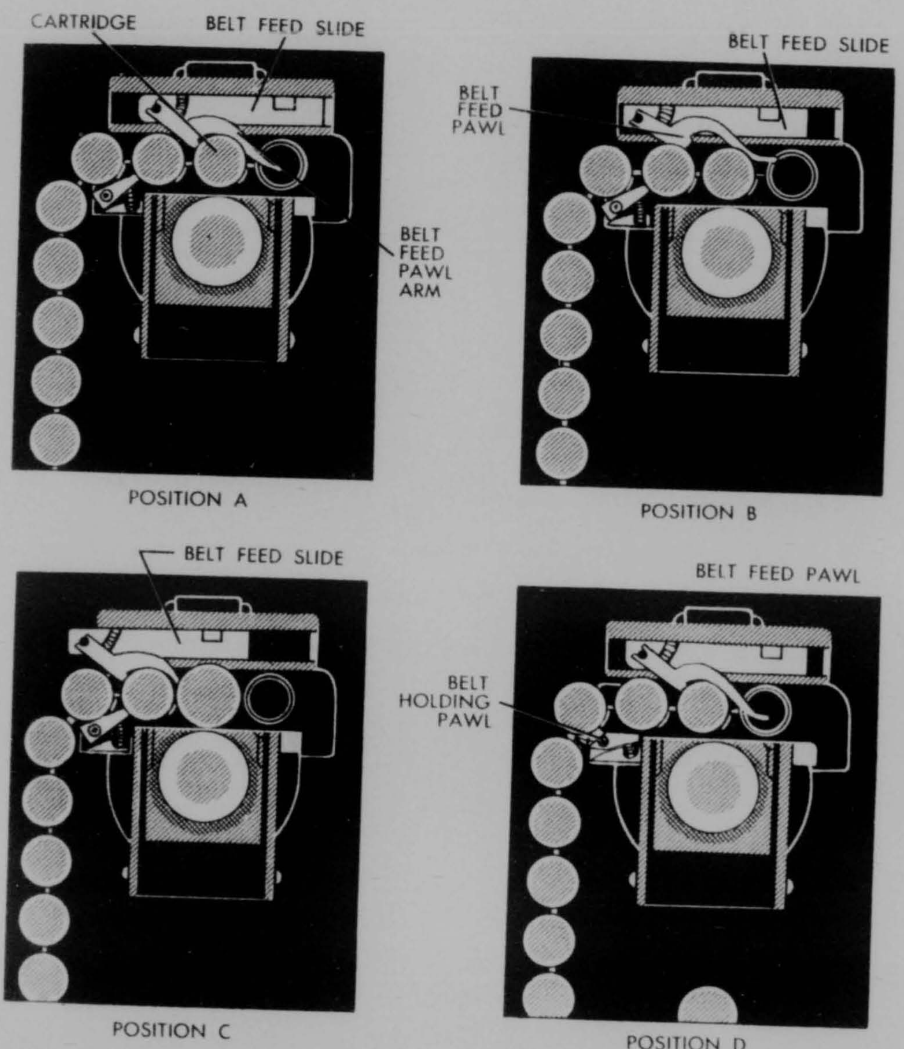

Figure 2–62. Cycle of Feeding—Showing Position of Belt Feed and Holding Pawls—Cross Section View.

extracted as the belt-feed slide starts moving out to engage and pull the belt into the gun, the belt-feed pawl arm attached to the pawl rides over this unextracted cartridge and lifts the pawl so that it cannot engage the belt. This prevents double feeding and consequent stoppage due to bent gun components.

Extracting and Ejecting

As recoil starts, a cartridge is drawn from the ammunition belt by the extractor. The empty case is withdrawn from the chamber by the T-slot in the front face of the bolt. Figure 2-63 shows a live cartridge being withdrawn from the belt by the extractor, and a fired cartridge being withdrawn from the chamber by the T-slot of the bolt, at the beginning of the recoil movement.

Note: The empty case, having been expanded by the force of the explosion, fits the chamber very tightly, and the possibility exists of tearing the case if the withdrawal is too rapid. To prevent this, and to insure slow initial withdrawal, the top front edge of the breech lock, and the front side of the notch in the bolt are beveled. Thus, before the bolt is completely unlocked, it has moved slightly away from the rear end of the barrel in a gradual manner.

As the bolt moves to the rear, the cover-extractor cam forces the extractor down, causing the cartridge to enter the T-slot in the bolt.

As the extractor is forced down, a lug on the side of the extractor rides against the top of the (extractor) switch on the side plate, causing the switch to pivot downward to the rear. Near the end of the rearward movement of the bolt, the lug on the extractor clears the end of the switch, and the switch snaps up to its normal position.

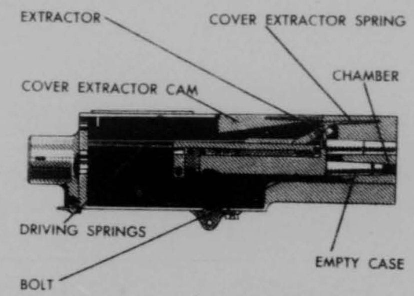

Figure 2—63. Extracting Cartridge from Ammunition Belt at Start of Recoil Movement.

On the counterrecoil movement, the extractor is forced farther down by the extractor lug riding under the (extractor) switch. This pushes the live cartridge into its correct position in the T-slot. At the same time, the live cartridge moving into place expels the empty cartridge case which has been withdrawn from the chamber. The extractor stop lug on the side of the bolt limits the downward travel of the extractor so that the cartridge, guided by the ejector, enters the chamber of the barrel. When the cartridge is partly chambered, the extractor rides up the extractor cam on the side plate, compresses the cover-extractor spring, and is forced down into the extractor groove of the next cartridge in the belt.

Note: The empty case of the last cartridge fired is forced out of the T-slot by the ejector.

SECTION IV — INSPECTION, MAINTENANCE AND REPAIR

1. GENERAL

This section contains the information needed for the performance of preventive maintenance services, scheduled lubrication, and adjustments and repair.

Cleaning and Preserving Materials

The following cleaners and preservatives are required for use with this materiel. TM 9-850 should be consulted for information additional to that contained in this manual on the use of these materials. Refer to WD Supply Catalog ORD 3, SNL K-1, for latest specifications.

Cleaner, rifle bore.

Cloth, crocus, sheets 9x11.

Cloth, wiping, cotton.

Compound, cleaning, alkaline type.

Oil, lubricating, preservative, medium.

Oil, lubricating, preservative, special.

Patches, cut, cotton flannel.

Soap, or issue.

Soda-ash.

Solvent, dry-cleaning.

Spare Parts, Tools, and Equipment

Spare Parts. A set of organizational spare parts is supplied to the using arm for field replacement of those parts most likely to become worn, broken, or otherwise unserviceable.

Tools and Equipment. Tools and equipment include items of issue required by personnel for disassembly, assembly, and cleaning and preserving of the gun. Equipment should not be used for purposes other than prescribed and, when not in use, should be properly stored in the chest and or roll provided for them.

List of Spare Parts, Tools and Equipment. Spare parts, tools, and equipment mentioned above, supplied for cal. .50 machine gun M3, are listed in WD Supply Catalog ORD 7 SNL A 67, which is the authority for requisitioning replacements.

Specially Designed Tools and Equipment

Certain tools and equipment listed in WD Supply Catalog ORD 7 SNL A 67 are specially designed for maintenance and repair operations on cal. .50 machine gun, M3. These tools and equipment are listed below for information only. This list is not to be used for requisitioning replacements.

Use of Equipment

Use of Ruptured Cartridge Case Extractor, Cal. .50, 41-E-557-50. This extractor (Figure 2-64) is designed for the purpose of extracting ruptured cartridge cases (head torn off) from the chamber of the barrel of guns equipped with Air Force chargers or like retracting devices. The use of the extractor is as follows:

The firing circuit is disconnected, the cover is raised and the gun fully unloaded. The bolt is retracted by means of the charger or other retracting device, and the ruptured cartridge extractor is placed in the T-slot of the bolt in the same manner as a cartridge so that it is held in line with the bore by the ejector of the extractor assembly of the gun. With the cover raised, it may be necessary to press the extractor assembly down by hand to align the ruptured cartridge case extractor with the bore.

When the ruptured cartridge extractor is in line with the bore and held firmly in the T-slot of the bolt, the bolt is allowed to spring forward into battery under action of the driving springs. This will force the ruptured cartridge extractor through the ruptured cartridge case and the shoulders on the extractor will spring out in front of the case.

The bolt is fully retracted by means of the

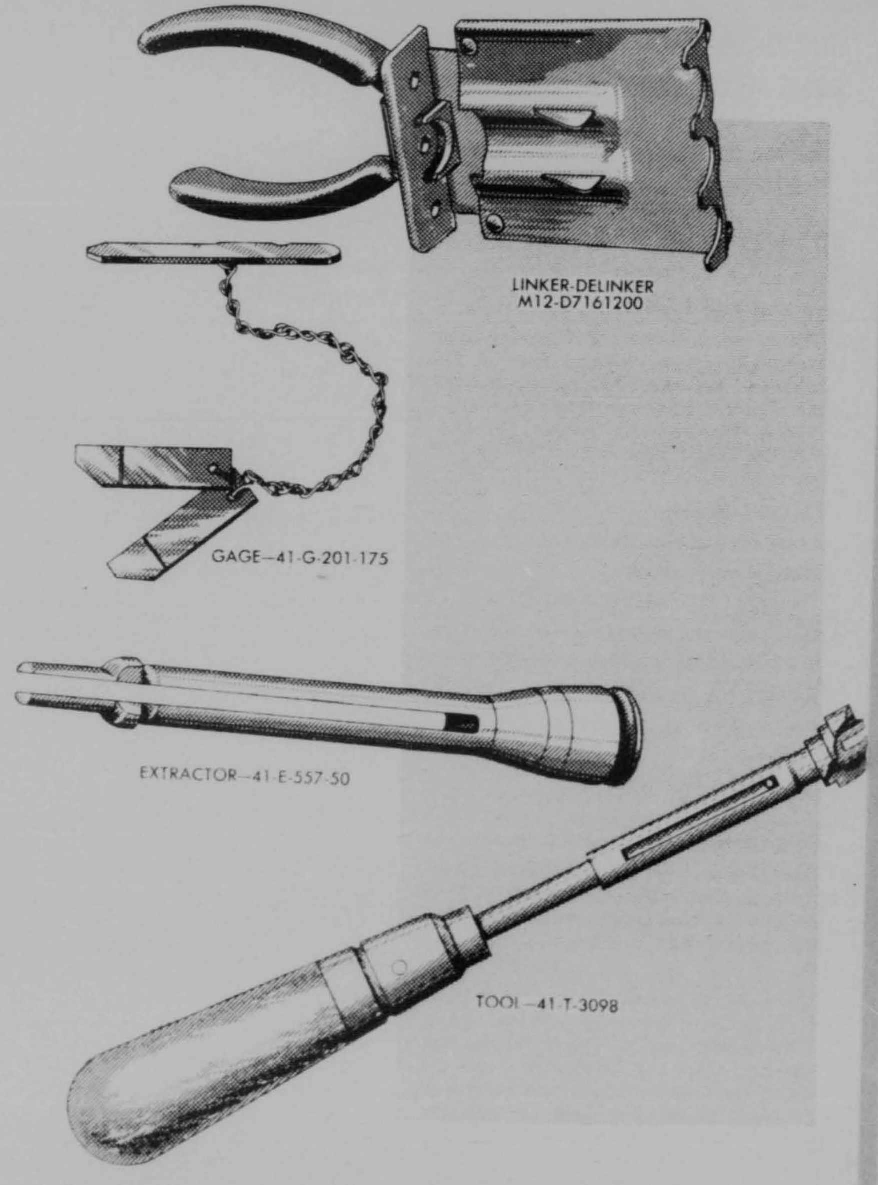

Figure 2—64. Ruptured Cartridge Extractor, Cal. .50 and Firing Pin Spring Removing Bolt.

charger or other retracting device. The ruptured case is then drawn from the chamber.

Note: If the gun is properly headspaced and timed, the ruptured cartridge extractor may be placed in the feedway, engaged with the extractor of the gun, and the cover closed. The extractor can then be fed into the T-slot like an ordinary cartridge.

Hand Cartridge Linker-delinker, Cal. .50, M12. This tool (Figure 2-65) can be used to extract a defective cartridge quickly and relink at any point in a cal. .50 metallic link belt. It will also position three cartridges. In general the tool consists of a base, slide, and handle assembly and is operated as follows:

To extract a cartridge from the link belt, the handles of the tool are spread and the extractor dog positioned (Figure 2-65) in front of the rear flange by pushing on the dog cam. The cartridge to be extracted is placed in the middle of the base with the extractor groove engaged by the extractor dog, and the rear of the link bearing upon the delinking posts, the handles are then squeezed together. The cartridge to be extracted, and the cartridge on either side, should be seated in the notches, in the front flange with the front of the links bearing upon it.

To splice two separate portions of ammunition belt, the rounds of which are held together by metallic links, a cartridge is inserted into the connecting links by hand as far as possible. The handles of the linker-delinker tool are pressed together and the extractor dog back is pressed back into its recess in the rear flange. The tool is placed under or over the cartridges so that they lie in the front-flange notches with the front of links bearing on the flange. The handles of the tool are spread as far as possible to force the cartridge fully into the links. Cartridges can be aligned in belts in a similar manner. Pivots should be lubricated occasionally, to insure smooth action, and wiped dry of excess oil.

Use of Linking-delinking Machine, Cal. .50, M7

This machine (Figure 2-66) can be used to delink and link ammunition in a cal. .50 metallic link belt. In general the machine consists of a base, handle, slide (bar) and delinker (bar), and is operated as follows:

To delink ammunition, the handle is partly raised and the belted ammunition is laid on the base with the separating pins between the cartridges and the links against the pins. The handle then is lowered until the delinker engages the extractor grooves in the cartridges, the delinker is held in position and the handle

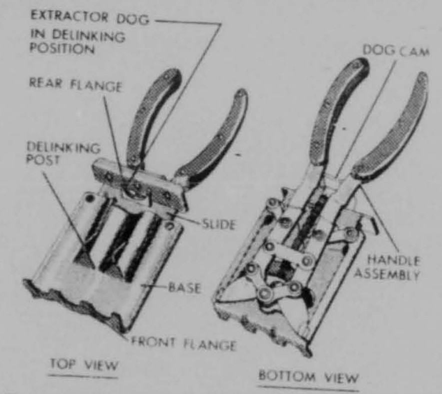

Figure 2—65. Hand Cartridge Linker-Delinker, Cal. .50 M12 (D7161200)—Showing Parts.

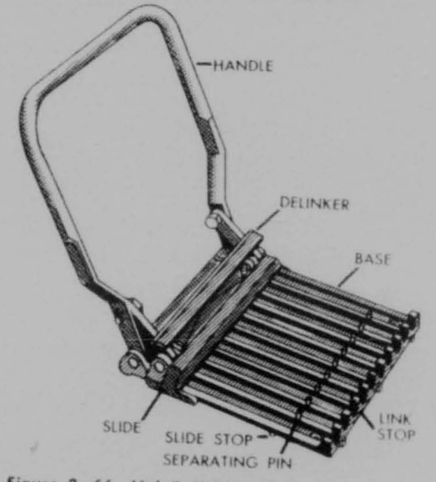

Figure 2—66. Link-Delinking Machine, Cal. .50, M7 (D7160003)—Showing Parts.

is raised. This will cause the delinker to move rearward and pull the cartridges from the links.

To link ammunition, the links are assembled and placed on the base adjacent to the U-shaped link stops, cartridges then are placed in the grooves of the base, and started into the links. With the delinker raised, the handle is lowered until the slide presses against the base of the cartridges which are then forced forward into the links. The handle is moved down until the slide is checked by the slide stops on the sides of the base. The cartridges will then be loaded to the correct depth in the links. Care should be taken to position properly that portion of the loaded belt which is adjacent to the section being loaded. Pivot pins should be cleaned and lubricated occasionally to insure smooth action and wiped dry of excess oil.

2. LUBRICATION

General Lubrication Instructions

Lubrication. To lubricate the gun prior to flight, preservative lubricating oil (special) is used. The oil prescribed insures proper functioning at all temperatures likely to be experienced during flight.

Lubrication should be accomplished carefully and sparingly. Excess oil should be wiped off. This is particularly important with regard to the bolt and rear end of the barrel of the gun in order to keep oil from getting into the chamber. Unnecessary oil or grease in the chamber of the barrel will raise the breech pressure to a hazardous point when the gun is fired and may result in a blown bolt, a ruined gun, and serious injury to personnel.

Excess oil holds grit and foreign matter blown on to it and as a result may clog the mechanism and cause a malfunction or stoppage. In any case it will cause excessive wear to the moving parts. Lubrication is best accomplished with a clean, lintless cloth saturated in the proper lubricant, wrung out, and then wiped over the surface.

Smoking of the operating mechanism of the gun when firing may indicate excessive lubrication.

Excess oil should be wiped from the bore and chamber of the barrel before firing or mounting guns for combat. Only a very light film should be used.

Note: The term "lubrication" as used in this manual applies both to the lubrication of moving, contacting surfaces to minimize friction and to covering stationary parts with an oil film to prevent rusting.

Cleaning Prior to Lubrication. Unless otherwise specified, the rifle-bore cleaner (preferred) or dry-cleaning solvent is used to clean or wash all metal parts whenever partial or total disassembly is undertaken, or when renewing the protective lubricant films on metal surfaces. The use of gasoline or benzine for cleaning is prohibited. All parts should be dried thoroughly and lubricated immediately after cleaning to prevent quick rusting.

When cleaning the bolt assembly care should be taken to insure complete removal of all oil or residue.

Points in Gun to be Lubricated

All bearing surfaces of moving parts should be lightly lubricated. In addition to the general lubrication of the gun as explained above, special attention should be given to the following points:

- Cover extractor cam.
- Cover extractor spring.
- Guideways of the belt-feed slide.
- Cocking lever.
- Belt-feed lever grooves in the bolt.
- Guideways in the barrel extension taking the bolt guides.
- Breech-lock cam guides and top.
- Switch pivot.
- Breech lock.
- Extractor pivot.
- Sear guides and slide.
- Belt-feed lever pivot stud and slide guides.
- Cleaning and lubrication of gun daily, and after firing.

3. PREVENTIVE MAINTENANCE SERVICE

Scope

Preventive maintenance service prescribed by Army Regulations is a function of using organization echelons of maintenance. This section contains important general preventive maintenance procedure, and specific maintenance procedure applying to the gun as a whole. It also contains schedules of preventive maintenance service allocated to crew and to organizational maintenance. Special maintenance of specific groups of the gun components is covered, when necessary, in sections pertaining to the groups.

General Procedures

The following general preventive maintenance should be observed in addition to the organizational maintenance schedules.

The importance of a thorough knowledge of how to clean and lubricate the machine gun cannot be over-emphasized. The kind of attention given to this weapon largely determines whether the gun will shoot accurately and function properly when needed.

Rust, dirt, grit, gummed oil, and water cause rapid deterioration of internal mechanism and outer unpainted surfaces. Particular care should be taken to keep all bearing surfaces and exposed parts clean and properly lubricated. Wiping cloths, rifle-bore cleaner, dry-cleaning solvent, and lubricants are furnished for this purpose. All traces of rust are removed from surfaces with crocus cloth, which is the coarsest abrasive to be used by the using arm for this purpose. Care should be taken not to change the shape or dimension of the part.

Loose parts should be tightened; unserviceable parts should be replaced.

Serious damage to weapons, in many cases requiring repair and replacement of component parts, has resulted from the use of water, steam, or air from a high-pressure hose used for cleaning purposes. For this reason, all personnel are cautioned to prevent water, dirt, or grit from entering functioning parts and bearing surfaces. The safest method of cleaning is prescribed in the following paragraph.

Each time a gun is disassembled for cleaning or repair, all parts should be carefully inspected for cracks, excessive wear, rust, and like defects which might cause malfunction of the gun. All parts should be thoroughly cleaned and properly lubricated before assembly.

Each time a gun is assembled, it should be given an operational check after headspace and timing have been checked and adjusted. This check consists of operating the gun by hand to see that it functions properly. When possible a belt of dummy cartridges should be fed through the gun to be sure that feeding, extraction, chambering, and ejection are properly executed by the mechanism.

When materiel is not in use, the proper covers should be used.

Spare parts, tools, and equipment should be inspected for completeness, serviceability, and interchangeability. Missing or damaged items are replaced or turned in for repair. Only tools which are provided should be used. Tools which do not fit will fail or cause damage to parts.

At least every six months a check-up is made to see that all modifications have been applied. No alteration or modification which will affect the moving parts should be made by the using personnel, except as authorized by the Ordnance Department.

4. SPECIFIC PROCEDURES

Before Firing. The bore and chamber are thoroughly cleaned of all dirt, excess oil, or grease.

Using clean wiping cloth dipped in proper oil and then wrung out, any surplus oil is wiped from the bolt, feedway, and cover assembly.

Outer surfaces of the gun are wiped with clean wiping cloth dipped in proper oil and wrung out.

After Firing—Barrel. The following cleaning procedure is followed at the end of the day's firing. If no firing is anticipated, it is to be repeated on three consecutive days thereafter.

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To clean bore and chamber, two clean patches are placed in the slot of the cleaning rod; the patches are saturated with rifle-bore cleaner, and moved back and forth through the barrel several times. If rust spots or foreign matter are not removed by the bore cleaner, the cleaning brush M4 is attached to the cleaning rod and the lands and grooves are scrubbed. The chamber-cleaning brush M6 should be used to clean the chamber. A light coating of rifle-bore cleaner should be allowed to remain in the bore between cleanings to prevent rust.

After the fourth cleaning following firing (if no firing is anticipated within next twenty-four hours), clean dry patches are placed in the slot of the cleaning rod and bore and chamber thoroughly dried. With clean dry patches dipped in preservative lubricating oil (special) and then wrung out, a light film of oil is applied to the bore and chamber by working the patches through the bore. Excess oil must be removed from the bore and chamber before firing.

Soap and water or soda ash solution are used after firing if rifle-bore cleaner is not available. The barrel is placed, muzzle down, in a vessel containing a solution of ½ pound of soda ash to each gallon of water. Two patches are attached to the cleaning rod, the rod is inserted in the breech end of the barrel, and moved forward and backward for about one minute, pumping the solution in and out of the bore through its entire length. If this does not remove rust or foreign matter, the lands and grooves of the bore, as well as the chamber, are scrubbed, while still wet, with the cleaning brush M4 attached to the cleaning rod. Then clean water is pumped through the bore, using clean patches. The chamber cleaning brush M6 should be used to clean the chamber. The bore and chamber are then wiped thoroughly and lubricated as prescribed above. This procedure is repeated on three consecutive days thereafter, followed by drying and lubrication as described above.

Note: If soda ash is not available, a solution of one pound of issue soap to each gallon of hot water may be used, or hot water may be used alone.

Caution: Dry-cleaning solvent should not be used because the corrosive salts from the primer composition, which cause rust, are not readily dissolved by petroleum products; they are, however, readily dissolved by water-base solutions.

After Firing—Parts Other Than Barrel. With rifle-bore cleaner or dry-cleaning solvent, the front face of the bolt and the front of the barrel extension, as well as all the cover group components which have been exposed to powder gases, are thoroughly cleaned. Dirt and foreign matter must be removed from all other parts. (After cleaning, cleaned parts should be handled with gloves as acid from hands accelerates rusting.)

Caution: Special care should be used to remove all fouling from the firing pin hole in the face of the bolt.

During firing, hard carbon gradually accumulates in the recoil booster and sometimes in the T-slot of the bolt. This carbon deposit must be carefully removed, with a scraper or crocus cloth, and the parts lubricated immediately.

All components should be thoroughly dried and a light coating of preservative lubricating oil (special) immediately applied.

Daily Service. The bore and chamber are inspected. Component parts are cleaned, wiped thoroughly dry and relubricated.

Weekly Service. If the gun has not been fired, oil film in the bore and chamber should be renewed every five days, using a single patch saturated in preservative lubricating oil (special). When operating from areas of high humidity or salt spray, and atmospheric temperatures are in excess of +32°F, in event guns are not being maintained in readiness for immediate action, preservative lubricating oil (medium) is used. In this case the medium oil must be thoroughly removed and the guns relubricated with the special oil before being placed in action. All excess oil is wiped from the bore and chamber before firing or preparing for combat, and inspected for traces of rust formation.

Care of Spare Parts and Equipment. Complete sets of spare parts, tools, and equipment should be maintained at all times, kept lubricated to prevent rusting and inspected at frequent intervals. When in actual (but not daily) use, they should be coated with preservative lubricating oil (medium). When in use, or placed in the airplane for emergency use, they should be cleaned with dry-cleaning solvent and lightly lubricated with preservative lubricating oil (special).

5. ADJUSTMENTS AND CHECKING

Headspace

Definition. The headspace of military weapons in general, with the cartridge fully seated in the chamber, is the distance between the base of the cartridge and the face of the bolt. This definition cannot be applied to aircraft machine guns due to the fact that in machine guns the distance between the face of the bolt and the base of the cartridge is controlled by the depth of the T-slot in the bolt. Therefore, in aircraft machine guns the headspace, for all practical purposes, may be defined as the distance between the rear face of the barrel and the face of the bolt which presses against the base of the cartridge.

Significance. When any cartridge is fired, the powder gases exert tremendous pressure in the chamber. This pressure forces the bullet out of the barrel; it also tends to force the cartridge case out of the chamber. The cartridge case, therefore, must be held snugly in the chamber from the time the cartridge is fired until the bullet leaves the barrel. It is held there by the forward face of the bolt pressing against the rear face of the cartridge, the bolt being locked in this position by the breech lock. The breech lock engages a recess in the bottom of the bolt and locks it firmly to the barrel extension. As the recoiling parts move into battery after recoil, the breech lock is forced upward by the breech lock cam and locks the bolt to the barrel extension just before they reach the battery position.

Tight Headspace. Improper adjustment of the parts resulting in too little headspace may cause the following malfunctions:

Failure of the recoiling parts to go completely into battery because the breech lock cannot fully enter the locking recess of the bolt.

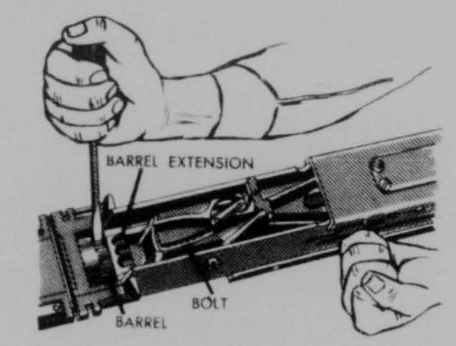

Figure 2—67. Screwing Barrel Into Barrel Extension (Link Chute Adapter Removed to Show Operation).

Failure to fire because the bolt may not go forward far enough for the sear to be released.

Sluggish fire because of binding and excessive friction between the moving parts (particularly noticeable when pulling a long ammunition belt).

Loose Headspace. Improper adjustment of parts resulting in too much headspace may cause the following malfunctions:

Rupture of the cartridge case because the barrel bolt is too far forward in the barrel extension for the face of the bolt to hold the cartridge snugly in the chamber.

Inability to obtain proper timing.

Battering of the breech lock, bolt and barrel extension because the locking surfaces of the breech lock and bolt recess are not in contact at the instant of firing. (This will soon render these parts unfit for service.)

Battered T-slot lips due to the bolt striking the barrel extension.

When and How to Adjust Headspace. The gun must be headspaced each time it is assembled. The adjustment must be made after the parts are assembled into the gun. If a gauge is not available, the following method for headspacing basic aircraft machine gun, cal. .50, M3 may be used:

The bolt is pulled back about one inch by means of the bolt handle, or other retracting device.

The barrel is screwed into the barrel ex-

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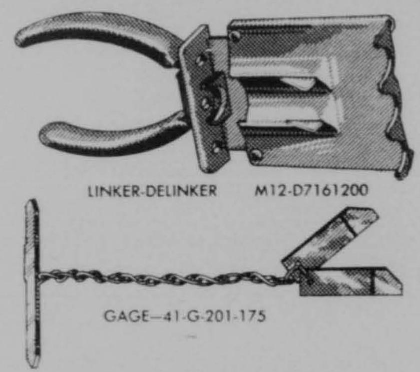

Figure 2–68. Hand Cartridge Linker-Delinker, Cal. .50 M12, and Headspace and Timing Gauge, Cal. .50.

tension by applying a screw driver to the notches on the rear end of the barrel (Figure 2-67) until the recoiling parts will not go into battery position without being forced when the bolt is released. (The recoiling parts are in battery when the barrel extension touches the trunnion block.)

Note: For ease in screwing the barrel into the barrel extension, the link-chute adapter assembly should be removed.

The barrel is screwed out of the barrel extension one notch at a time until the recoiling parts will just go into battery position when the bolt is released, but it should not be forced forward.

Note: The bolt should not be retracted more than one inch when determining the point at which the recoiling parts will just go into battery without being forced.

When this point is found, the bolt is retracted and the barrel unscrewed two more notches.

When and How to Check Headspace. The headspace should be checked each time it is adjusted, prior to test firing on the ground; after installation of the gun in an airplane, prior to each take-off of the airplane; and at any other time that there is doubt as to correctness of the headspace. Headspace gauge A351211 ("GO" and "NO-GO") is used to check the headspace of all machine guns, cal.

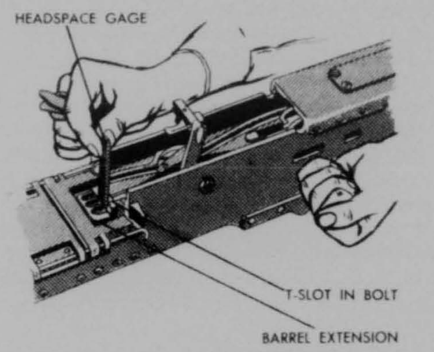

Figure 2–69. Inserting Headspace Gauge (Link Chute Adapter Removed to Show Operation).

.50. This gauge is a part of the headspace and timing gauge assembly 41-G-201-175 (Figure 2-68). To check headspace the procedure is as follows:

The gun is cocked by fully retracting the recoiling parts and allowing them to return to battery position. (This cocks the firing pin.)

The bolt is retracted until the barrel extension and trunnion block are separated approximately $\frac{1}{16}$ inch. This puts the locking surfaces of the breech lock and bolt in contact, which is the position they will assume when a cartridge is chambered.

The "go" end of the headspace gauge is inserted in the T-slot between the face of the bolt and the end of the barrel (Figure 2-69). If the gauge does not go in, the headspace is too tight; the adjustment is corrected by unscrewing the barrel, one notch at a time, checking with the gauge each time, until the gauge enters.

An attempt is made to insert the "no-go" end of the headspace gauge in the T-slot between the face of the bolt and the end of the barrel. If the "no-go" end of the gauge goes in, the headspace is too loose; the adjustment is corrected by screwing the barrel into the barrel extension one notch at a time, checking with the gauge each time, until the "no-go" end of the gauge will not enter. If the gauge does not go in and the check for tightness outlined in step mentioned above is satisfactory, the headspace is correct.

The gauge is then removed and the firing pin released.

Caution: The firing pin with the gauge in place must not be released, as this will damage the firing pin.

Note: If the headspace obtained by the method of adjustment given above is not between the "go" and "no-go" limits of the gauge, the headspace is changed to suit the gauge.

The gauge may be inserted from either the top or bottom of the gun. In the event the gauge is inserted from the bottom, the slack between the bolt and the breech lock may be taken up by inserting a screw driver in the T-slot between the face of the bolt and the end of the barrel.

Timing

Purpose of Timing Check. The purpose of a timing check is to insure that the gun is not fired too early or too late by any of the various means employed to fire the weapon. In extreme cases of early timing the gun will fire two rounds and then stop because recoil from the second round fired started before the extractor was far enough forward to engage the next cartridge in the belt. The gun must not fire earlier than 0.116 inch out of battery. On the other hand, if the gun fires too late while firing automatically, the barrel extension will strike the trunnion block as the recoiling parts move forward on the counterrecoil movement. During automatic firing, the gun must fire before the barrel extension reaches a point 0.020 inch out of battery. The procedure for making the adjustment, as well as the point at which the firing pin is released, is referred to as "timing."

When to Check Timing. Due to vibration when parts become worn, or as a result of disassembly, adjustment of the trigger bar or firing device may be disturbed. Timing should be checked whenever headspace is checked and whenever timing is in doubt. Synchronized guns need not be checked for timing unless failures to feed because of poor timing are encountered during actual firing.

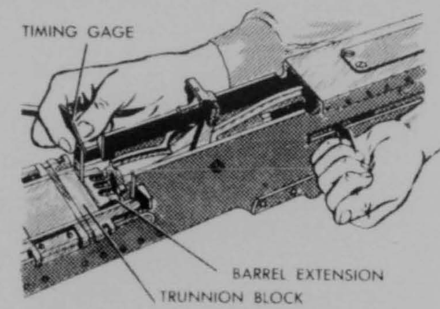

Figure 2–70. Inserting Timing Gauge (Link Chute Adapter Removed to Show Operation).

Caution: In guns equipped with trigger bars assembled for use with a top-plate solenoid, care should be taken that the trigger bar does not drag on the bolt. (In any other case, the adjustable trigger-bar stop spring always acts to hold the trigger bar up and away from the bolt.)

Timing Check to Insure That the Gun Will Not Fire Too Late. The procedure is as follows:

The headspace is checked.

The gun is cocked by fully retracting the recoiling parts and allowing them to go forward into battery.

The cover is raised and the bolt retracted slightly ($\frac{1}{4}$ inch).

The "fire" timing gauge (0.020 inch) of the gauge assembly 41-G-201-175 (Figure 2-70) is inserted between the barrel extension and the trunnion block, as shown in Figure 2-70.

The barrel extension is allowed to close slowly on the gauge.

The firing mechanism is released by operating once the solenoid or other firing device. The firing pin should release smartly. If the firing pin is not released, the solenoid protrusion or the adjustable trigger-bar stop must be adjusted until the firing pin can be released with the "fire" gauge in place.

Note: A trigger bar B7162196 is furnished with the gun M3 for use with a top-plate solenoid.

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To adjust the trigger bar, the backplate is removed and the trigger-bar stop adjusting nut (Figure 2-50) is turned to the right one notch at a time until the firing pin can be released with the "fire" gauge in place.

Note: To secure earlier timing the nut is turned to the right. To secure later timing the nut is turned to the left. One click (notch) of adjustment is equal to 0.004 inch change in distance between the toe of the trigger bar and the top of bolt.

Caution: Care should be taken to prevent the toe of the trigger bar from touching the top of the bolt. Clearance, which can be measured with a feeler gauge, should not be less than 0.005 inch, if possible.

Timing Check to Insure That Gun Will Not Fire Too Early. Procedure is as follows:

The "fire" timing gauge is removed, the gun is cocked, and the "no-fire" (0.116 inch) gauge of the gauge assembly 41-G-201-175 (Figure 2-68) is inserted between the barrel extension and the trunnion block.

The barrel extension is allowed to close slowly on the gauge.

The firing mechanism is released once. The firing pin should not be released.

If the firing pin is released with the "no-fire" gauge in place, the solenoid protrusion or the adjustable trigger-bar stop must be adjusted to obtain the desired results.

To adjust the trigger bar the backplate is removed and the trigger-bar stop adjusting nut (Figure 2-50) turned to the left one notch at a time until the firing pin cannot be released with the "no-fire" gauge in place.

6. MALFUNCTIONS AND CORRECTIONS

General

It is important that the gun and all its equipment be properly installed and maintained. Proper care of the gun and attention to the preventive maintenance schedules will greatly reduce the possibility of gun stoppages due to malfunctions. When trouble develops, equipment should be carefully checked before assuming that the gun itself is re-

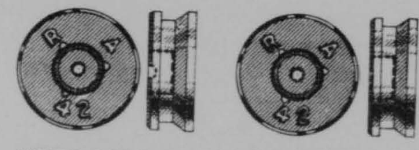

Figure 2–71. Normal and Light Indent in the Primer.

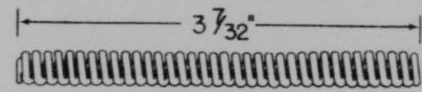

Figure 2–72. Firing Pin Spring.

sponsible for the stoppage. Excessive belt load or any of the equipment applied to the gun may cause the gun to cease firing through no fault of its own.

The first step in analyzing a malfunction is to observe carefully the position of the recoiling parts of the gun as an indication of the probable cause of the stoppage.

Before raising the cover, the feedway is inspected, whenever possible, by looking in at the side, to determine if the stoppage may be caused by misalignment due to improper loading of cartridges in the belt, short rounds, or other causes.

The bolt is held in the position at which the stoppage occurred, the cover is raised, and the gun inspected carefully. Unless the bolt is held in position when the cover is raised, the recoiling parts may spring forward toward battery position and the evidence as to the cause of the stoppage may be destroyed.

The gun should be fully unloaded and the recoiling parts moved forward and backward slowly by hand, watching for any binding or unusual friction which might have caused the stoppage.

Since most of the common malfunctions fall in one of five general categories, indicated by the position of the recoiling parts of the gun at the time of stoppage, these five categories with probable causes and remedies of the stoppages are covered in the following paragraphs of this section. On the basis of the report given by the gunner or pilot, the

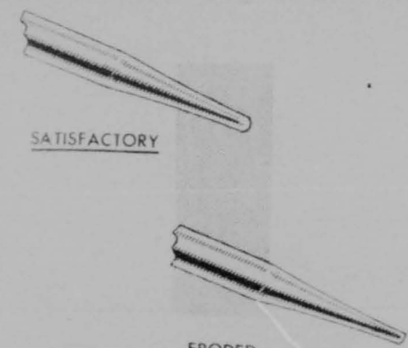

Figure 2–73. Firing Pin Showing Satisfactory and Eroded Point.

evidence available should be carefully analyzed—position of the recoiling parts when the stoppage occurred, points of friction between moving parts, etc.—and a decision made as to which of the categories the stoppage belongs. This procedure may save much time in finding the cause of the stoppage.

Gun Stops Firing in Battery Position with Live Cartridge in the Chamber

This condition is probably caused by one of the following:

Firing-pin Extension Binding in its Tunnel in Bolt. The bolt is removed from the gun and the firing-pin extension and firing pin taken out. The firing pin is dropped into its tunnel in the bolt; the striker should project approximately 1/16 inch from the face of the bolt. The bolt is then inverted; the firing pin should fall out freely. These operations are repeated with the firing-pin extension attached to the firing pin. The same freedom of movement mentioned above should be obtained. If any binding or unusual friction is discovered, the tunnel is cleaned thoroughly and, using crocus cloth or a fine grained sharpening stone, any burrs or roughness on the firing-pin extension or firing pin are removed and the parts lubricated lightly.

Caution: Abrasive should not be used on the firing-pin point. If necessary, the pin should be replaced.

Firing-pin Spring Weak or Broken. The spring may fail to drive the firing pin with sufficient force to fire the cartridge. This is indicated by a light indent in the primer (Figure 2-71). The spring is removed and the free length of the spring checked against that shown in Figure 2-72. If the spring is short, broken, or damaged, the firing-pin extension assembly must be replaced.

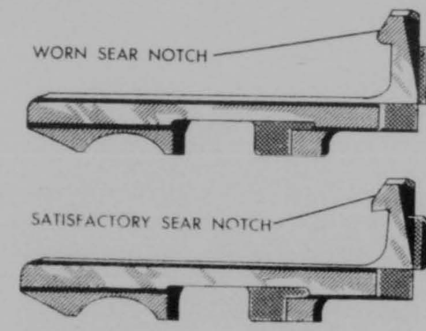

Figure 2–74. Sear Showing Satisfactory and Worn Notch.

Grease or Dirt in Firing-pin Spring. This condition is indicated by a light indent in the primer (Figure 2-71). Grease or excess oil in the firing-pin spring may congeal at low temperatures and cause failure to fire. Grease, oil and dirt must be thoroughly removed from the firing-pin spring, the firing pin and firing-pin extension, and the firing-pin tunnel in the bolt. The spring is removed, cleaned, and then lubricated.

Defective Ammunition. A defective primer, corroded ammunition, or a cartridge with the primer vent hole omitted will cause a misfire. If a normal firing-pin indent appears in the primer (Figure 2-71) and the cartridge is still unfired, it is an indication of a defective cartridge.

Firing-pin Point Worn or Broken. This condition is usually indicated by a very light indent in the primer. The tip of the firing pin may be broken off or eroded and deformed by blow-back of hot gases due to a punctured primer, as shown in the illustration at the right in Figure 2-73. The illustration on the left in Figure 2-73 shows the proper shape of the firing-pin point. Punctured primers are usually caused by a firing pin with excessive

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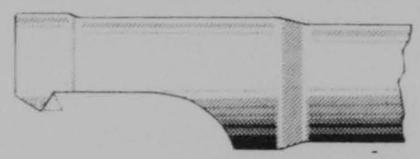

Figure 2–75. Firing Pin Extension Showing Worn Notch, Dotted Line Indicates Satisfactory Notch.

protrusion or a sharp point, or by hard brass in the primer. An enlarged firing-pin hole in the face of the bolt may also lead to pierced primers.

Worn Sear Notch. Wear on the sear notch, as shown in the right-hand illustration on Figure 2-74, may cause failure of the sear to engage the shoulder of the firing-pin extension properly. This may result in "failure to fire" or possible "uncontrolled fire." The proper shape of the sear notch is shown at the left in Figure 2-74. If badly worn, the notch will permit the firing-pin extension to ride forward with the cocking lever and result in failure to fire. If not too badly worn, the sear may hold the firing-pin extension rearward momentarily but not securely. This may result in a "run-away gun." A worn notch can also be the cause of light primer indents.

Worn Sear-engaging Notch of Firing-pin Extension. If the sear-engaging notch of the firing-pin extension is worn as shown in Figure 2-75, it may result in failure to fire or possibly "uncontrolled fire," because the shoulder may fail to engage the sear notch properly. The correct shape of the engaging shoulder of the firing-pin extension is indicated by the dotted line in Figure 2-75. A worn shoulder can also be the cause of light primer indents.

Weak Sear Spring. If the sear spring is weak or broken, it may fail to force the sear upward in time to engage the shoulder of the firing-pin extension. If weakness of the spring is suspected, the free length of the spring should be checked by laying the spring on the illustration in Figure 2-76, which shows the exact minimum free length of the spring. If the spring is shorter than the illustration, it should be replaced.

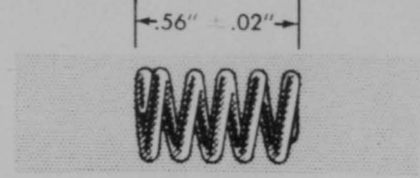

Figure 2–76. Sear Spring.

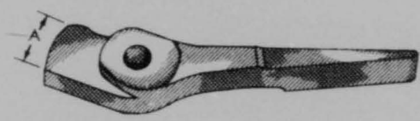

Figure 2–77. Cocking Lever ("A" Indicates Area Subject to Wear).

Broken or Worn Cocking Lever. If the cocking lever is broken it will fail to cock the gun. If the cocking lever is worn at the area indicated at "A" on Figure 2-77, it may fail to force the firing pin far enough rearward to engage the sear.

Gun Stops Firing in Battery Position with No Cartridge in Chamber

This condition is probably caused by one of the following:

Bent or Worn Belt-feed Lever. This may be caused by an excessive belt load such as is encountered when the free flow of the ammunition belt is impeded for any reason such as the misalignment of the ammunition feed chutes with the gun. A careful check should be made for such misalignment, particularly at the points where the base of the cartridge could catch and stop movement of the belt. The belt-feed lever may also be bent or broken if the belt-feed pawl arm has been broken and has thus permitted attempted double feeding when a cartridge has not been extracted from the belt.

Long Ammunition Belt Imposed Excessively Heavy Feeding Load. The force required to pull the belt into the gun must not be greater than thirty-five pounds without the aid of a booster. A check should be made for twisted belt chutes out of line, etc.

Belt-holding Pawl Springs Weak or Broken. If these springs are weak or broken, the belt

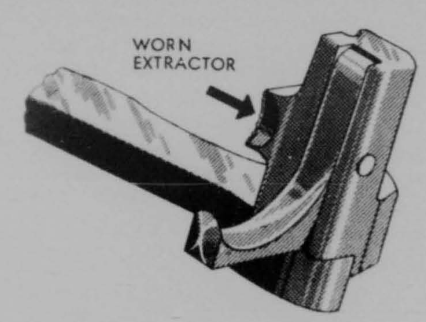

Figure 2–78. Worn Extractor.

links will slip back over the belt-holding pawl and the belt will not be properly positioned in the feedway. Grease or dirt in the spring recesses may also cause improper operation of the pawls.

Belt-feed Pawl Springs Weak or Broken. If these springs are weak or broken, the pawl will fail to engage the belt link firmly and a failure to feed may result.

Extractor May be Bent, Broken, or Deformed so that it Does Not Fit and Securely Engage Extractor Groove of Cartridge. Wear at the area indicated (Figure 2-78) may cause failure to extract the cartridge from the belt. A worn extractor should be replaced with an extractor assembly.

Gun Stops Firing with Recoiling Parts Out of Battery Position

This condition may be caused by any of the following:

Backplate Buffer Springs Broken. Broken backplate buffer springs may cause the gun to fail to complete the counterrecoil stroke, causing serious damage. Ordnance maintenance will replace broken springs since this item is not furnished to organizations. A light film of oil must be maintained on each spring.

Headspace Too Tight. A damaged or weak barrel-locking spring will cause the headspace to change. The headspace is checked and, if found incorrect, a check is made of barrel-locking spring for fracture, weakness, and worn projection. The headspace is then readjusted and checked.

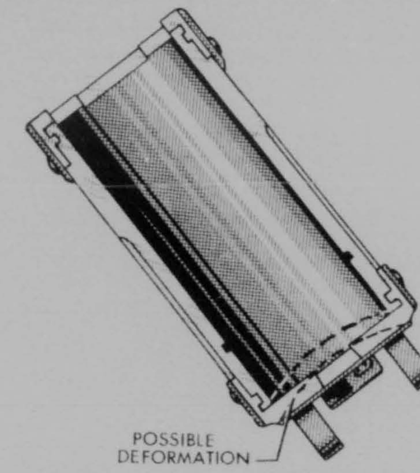

Figure 2–79. Receiver—Rear View (Dotted Lines Indicate Possible Deformation (Exaggerated) of Bottom Plate).

Bolt Binds Between Side Plates. If the gun is improperly mounted, the side plate may be twisted to such an extent that the bolt or barrel extension will bind and cause a stoppage. In such cases, the mounting of the gun should be checked.

Bolt Binds Against Top Plate Bracket. If the bottom plate is not flat, the bolt will be forced up against the top-plate bracket, and may cause the bolt to stop all the way to the rear when operating under full belt load. If the mounting bolts through the rear mounting lugs are drawn too tightly, the bottom plate may be sprung upward as indicated by the exaggerated white dotted line in Figure 2-79, causing the bolt to bind against the bracket.

Bolt Stud Binding in Slot of Side Plate. If such binding occurs, the bolt is likely to stop all the way to the rear when operating under full load. The edge of the side-plate slot should be stoned slightly to eliminate interference. If the stud section of the bolt handle or bolt stud is too long, the gun will not function properly because the stud will extend too far into the bolt and prevent movement of the sear. If the stud is too long, it will also force the collar out too firmly against the side plate.

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causing it to bind and catch in the slot. The distance from the retaining collar to the end of the stud inserted in the bolt should not be more than 0.585 inch.

Breech Lock Cam Excessively Tight. This will cause a binding between the guides of the breech lock cam and the barrel extension.

Firing-pin Hole Enlarged or Recoil Plate Not Flush with Face of Bolt. If the firing-pin hole in the recoil plate is enlarged, the firing pin will not be properly supported and the firing pin will be deformed. If the recoil plate is not flush with the face of the bolt, the primer will not be properly supported at the time of the explosion and the metal of the primer may be forced backward beyond the base of the cartridge, forming what is known as an "extruded primer." The projecting surface of the primer will cause the empty case to bind in the T-slot so that ejection cannot take place. On counterrecoil, the front end of the case will strike the barrel or barrel extension and cause the recoiling parts to stop out of battery position. Replacement of the bolt assembly will correct this condition.

Ruptured Cartridge Case in Chamber. A ruptured cartridge case which has not been extracted will stick in the chamber and prevent chambering of the following live cartridge. The ruptured cartridge case is removed, using the ruptured-cartridge extractor. Chamber and bore should then be thoroughly cleaned, and headspace and timing of the gun checked.

Side-plate Switch Does Not Complete Cycle in Time. A weak switch spring, or an installation on the aircraft which imparts vibratory motion to the switch, may cause the switch not always to complete its cycle in time. In this case, the extractor will ride the top of the switch during counterrecoil and the stoppage will occur in an "out-of-battery" position. The switch spring should be checked for proper strength and for vibration in installation.

Double Feeds. When feeding from the right-hand side, double feeds may occur with the present feed pawl because the pawl catches on the ears of the link. This stoppage may be recognized by the presence of distorted cartridge cases and broken links in the feedway. Condition of feed pawl should be examined and the unit replaced if necessary.

Gun Fires Two Rounds and Stops in Battery Position with No Cartridge in Chamber

If this condition continues after repeated chargings, it is probably due to early timing. With early timing, the gun is fired and recoil starts before the extractor has gone forward far enough to engage the cartridge in the feedway; therefore, the gun fires only the cartridge which was charged into chamber and that cartridge engaged by the extractor before firing started. The timing should be checked.

7. STORAGE AND SHIPMENT

General

Preparation of the materiel for domestic shipment will be the same as that prescribed for limited storage and/or standby storage.

Instructions for limited storage and/or standby storage include receiving inspection, preferred storage, preparation of materiel for storage, necessary inspections and servicing to insure safe storage and methods of removing from limited storage.

Instructions for domestic shipment include preparation of materiel for shipment, boxing and boxing data, and loading materiel in boxcars.

Materials required for preparation of materiel for storage and shipment throughout this section in addition to those listed previously.

Barrier, waterproof.

Compound, rust preventive, light.

Compound, rust preventive, medium.

Tape, adhesive, non-hygroscopic, O. D.

Wrapping, greaseproof.

Instructions for Limited Storage

General. When materiel is out of use, it must be turned over to ordnance personnel, or placed in a limited storage status for period not to exceed ninety days.

Note: Storage of materiel for periods in excess of ninety days normally will be handled by ordnance personnel only.

Receiving Inspection. Immediately upon receipt of materiel for storage, it must be inspected for missing or broken parts. If missing or broken parts cannot be replaced or repaired prior to placing the materiel in storage, a tag must be attached specifying the repairs needed; a written report of these items must be made to the officer in charge of the materiel.

Preferred Storage. The preferred type of storage is in closed, dry warehouses or sheds. When outdoor storage is necessary, materiel must be boxed and the storage site selected and arranged as prescribed in SB 9-47.

Preparation. All materiel received for domestic or overseas shipment should not be reprocessed for storage unless the inspections preparatory to or during storage reveal it necessary.

Cleaning. Alkaline solutions deteriorate phosphate finishes rapidly, and therefore are not to be used when degreasing materiel having a phosphate finish. Prior to cleaning, materiel is disassembled. The bore, all parts of the mechanism, and the exterior parts must be thoroughly cleaned and made free of foreign matter, using one or more of the following cleaning methods:

Rifle-bore Cleaner. Rifle-bore cleaner is preferred for degreasing materiel. Maximum cleaning efficiency will be obtained when used undiluted. When necessary to conserve the supply it may be diluted up to 50 per cent with water, provided prevailing temperatures are above +32°F.

Dry-cleaning Solvent. Dry-cleaning solvent may be used instead of rifle-bore cleaner as it does not harm phosphate finishes, dries rapidly, is noncorrosive, and has a fast degreasing action.

Vapor Degreasers. Vapor degreasers using trichlorenthylene are suitable for cleaning all materiel. Materiel cleaned in vapor degreasers must be immediately dipped in preservative lubricating oil (special) after the degreasing process. The natural dark color of phosphate finishes will be restored when oiled.

Hot Water Solutions. The efficiency of hot water solutions is accelerated to a greater extent by raising the temperatures of the solutions than by increasing the amount of materials in solution. Maximum results are obtained with a temperature of +180°F to +200°F.

Note: When hot water solutions are used, materiel must be thoroughly rinsed immediately in clear hot water to remove all traces of the solution which may promote deterioration of the finish.

For phosphate finishes, any one of the following materials may be used in the proportions shown, added to each gallon of water:

Borax .... 6 to 10 oz.

Issue soap .... Not more than 2 oz.

For nonphosphate finishes, any one of the following materials may be used in the proportion shown, added to each gallon of water.

Borax .... 1/2 to 1 lb.

Soda-ash .... 1/2 to 1 lb.

Castile or other available soap .... 1/4 lb.

Alkaline cleaning compound ...... 1/3 lb.

Drying. Dry all parts thoroughly with a lintless wiping cloth or dry compressed air, if available, and handle carefully to avoid contact with bare hands.

Caution: Unless special filters or moisture traps are used, compressed air will contain moisture and must not be used.

Application of Preservatives. Immediately after cleaning and drying, the gun is dipped in a hot bath of rust preventive compound (medium or light). The gun then is immersed at a 45-degree angle to avoid air bubbles in the barrel and receiver. The gun is allowed to remain in the bath until it reaches the same temperature as the bath. The gun is removed from the bath and the rust preventive compound allowed to set.

The gun is wrapped with type I or type II, grade C greaseproof wrapping at all places where it contacts the shipping box, bracing or cushioning.

The prepared gun is then placed in the shipping box as described previously. In addition to contents identification, the type of preservative applied (e.g., preserved with USA 121 Compound, Rust Preventive, medium) will be stenciled on the ends of the containers.

Inspections. A visual inspection must be made periodically to determine general condition. If corrosion is found on any part, the rust spots must be removed and the part cleaned and treated with the prescribed preservative.

Removal From Limited Storage. Materiel to be shipped should not be deprocessed unless inspection reveals that it is necessary to reprocess the materiel for shipment.

When it has been ascertained that materiel is to be placed into immediate service, any items noted, by a tag attached to materiel, as requiring repairs must be given a complete inspection, plus any repairs which are indicated by this inspection. Materiel is reprocessed as prescribed above and the prescribed lubrication applied.

Instructions for Domestic Shipment

General. If the materiel to be shipped will reach its destination within the scope of the limited storage period, it need not be reprocessed upon removal from storage, unless inspection reveals it is necessary.

Preparation. For the preparation of materiel for domestic shipment, see previous paragraph on preparation.

Shipping Container. Construction of the shipping container for the machine guns must be in accordance with TM 9-2854. The essential data necessary in the determination of storage space and shipping requirements is listed below:

	Unboxed	Boxed
Length (O. D. ft.)	4.78	5.30
Width (O. D. ft.)	0.41	0.66
Height (O. D. ft.)	0.57	0.84
Weight (lb.)	65	97
Volume (cu. ft.)	—	2.9
Ship ton	—	0.072

Loading Materiel in Boxcars. For the methods used in loading and bracing boxed items for rail shipment, refer to TM 9-2854.

CHAPTER 3—ROCKET LAUNCHERS

1. GENERAL

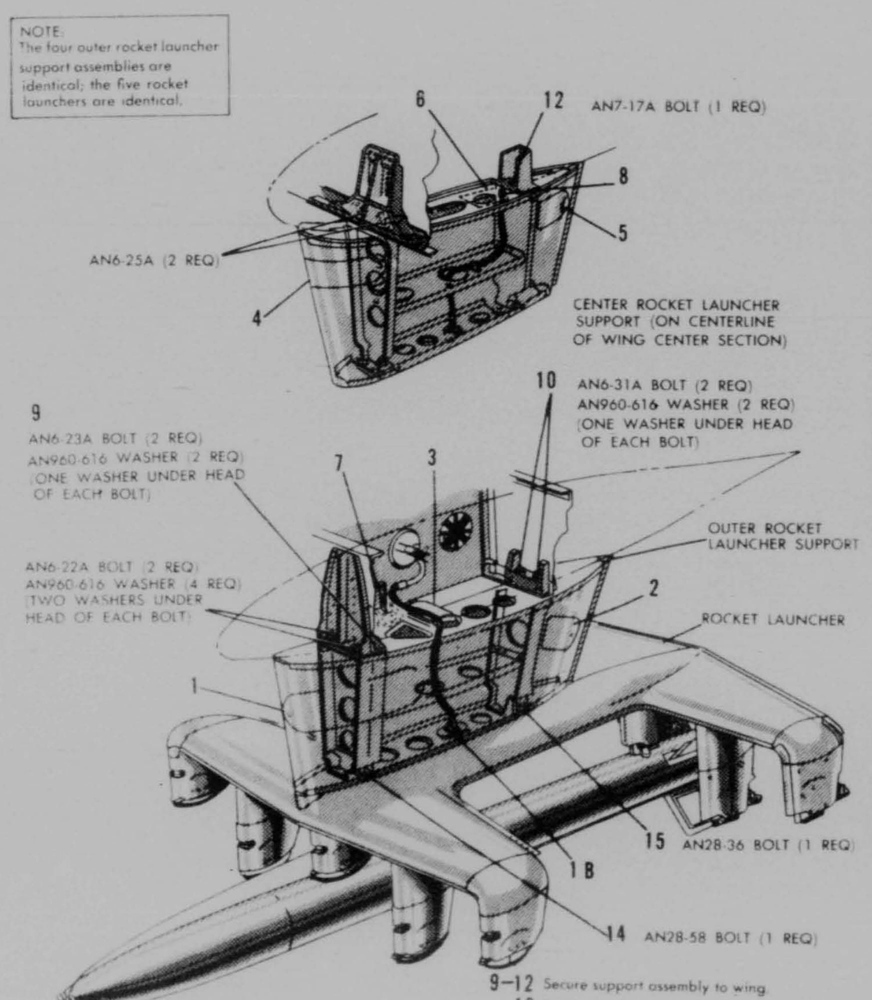
Existing aircraft rockets of the fin-stabilized type are too large to house and launch in sufficient numbers from within the airframes of present-day, high-speed, fighter-type airplanes. Such rockets, of necessity, are externally mounted beneath the wings or fuselage. In the past, fixed posts, pods, or pylons were used to support these rockets externally (Figure 3-1). These launchers remained attached to the airplane even after rocket firing and created considerable drag through the entire flight of the aircraft. Also, no provisions were made for jettisoning the rocket load in flight in the event of failure to fire or other emergency. The advent of faster airplanes demanded decreased drag and emergency means of ridding the aircraft of its external, drag-inducing load.

Retractable Post-flush-mount

The retractable post-flush-mount rocket launcher is designed to provide suitable means for carrying externally, launching, and jettisoning finned-type aircraft rockets from high-speed airplanes and to leave the airplane contour as clean as possible after expending the rockets. This is accomplished by causing the protruding rocket supports to retract fully into the airplane wing or fuselage automatically after firing or jettisoning the rockets. In addition, special design of the launcher and certain external components of the rocket make it possible to suspend two rockets from each launcher, a method called "double shot" or tier mounting, by attaching one rocket to another (Figures 3-3, 3 and 4).

2. PRINCIPAL COMPONENTS

The front post is retractable automatically, after firing or jettisoning of the rocket, to a position flush with the normal contour of the wing or fuselage. It must be capable of being withdrawn by hand or ordinary screwdriver from its retracted position to its extended position where it can be locked prior to loading without the insertion of extra or loose parts. It is imperative that no special tools or equipment be required to extend and lock the posts. The front post, which is required to have a



1–6 Remove access doors from support assemblies and wing.

7, 8 Position support assemblies. For outer supports, drop electrical connector through support. For center support, connect plug in wing, and secure with .020-inch safety wire.

9–12 Secure support assembly to wing.

13 Position rocket launcher. Connect plug to socket in support assembly; safety plug with .020-inch safety wire.

14, 15 Secure rocket launcher to support.

16 Replace access doors.

Figure 3–1. Installing and Removing Rocket Launchers.

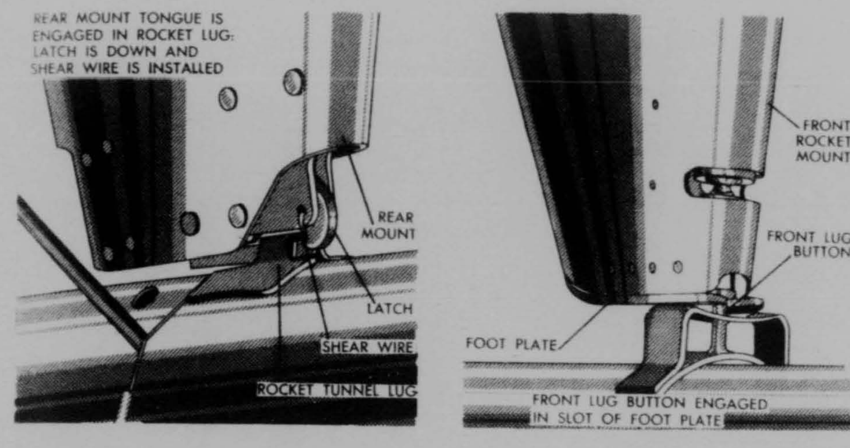


Figure 3–2. Rocket Mounts with Rocket Installed.

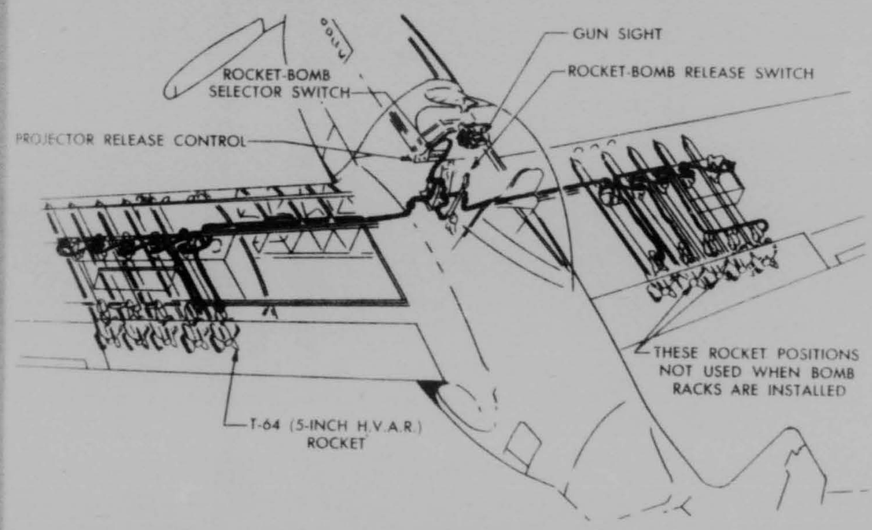


Figure 3–3. Rocket Equipment.

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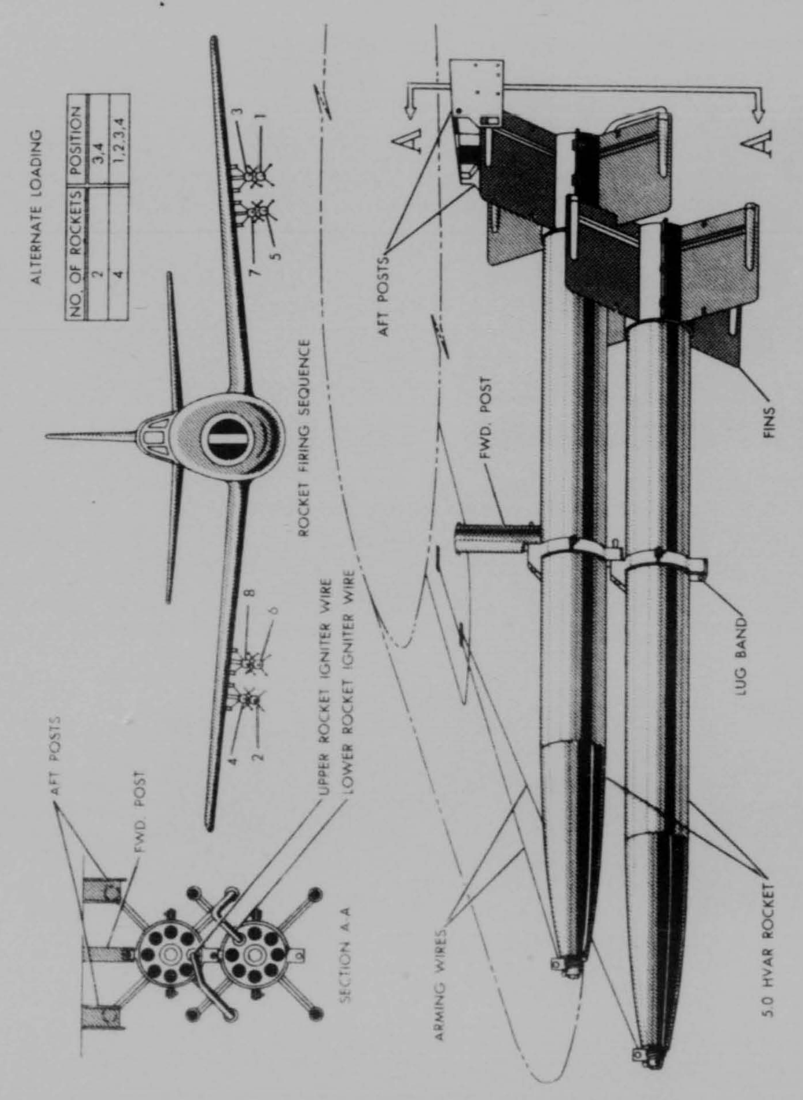
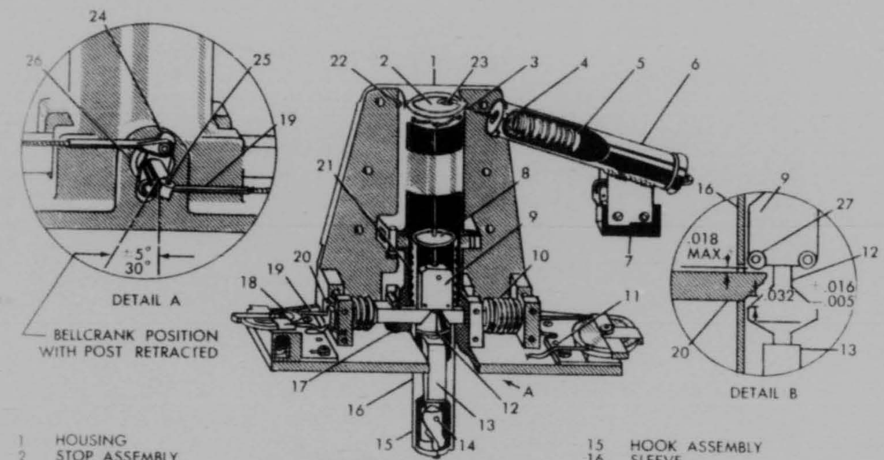


Figure 3—4. Rocket Installation.



1 HOUSING
2 STOP ASSEMBLY
3 CABLE
4 SPRING
5 PLUNGER
6 RETRACTING CYL.
7 UP LIMIT SWITCH
8 PLUG
9 STEM CAP
10 SPRING (2)
11 PULLEY BRACKET LOCATING PIN
12 STEM BODY
13 LOWER STEM
14 PIN
15 HOOK ASSEMBLY
16 SLEEVE
17 LOCK PIN GUIDE ROLLERS (8)
18 PULLEY (2)
19 CABLE (2)
20 LOCK PIN (2)
21 SLEEVE RETURN SPRING
22 SCREW (6)
23 PULLEY
24 BELLCRANK
25 JETTISON ACTUATOR DRIVE SHAFT
26 BEARING
27 ROLLERS (2)

*NOTE: WHEN 30X19710 MANDREL IS INSERTED IN HOOK (15) AND ROLLER (27) AND LOCKPIN (20) ARE IN CONTACT, GAP BETWEEN STEM (12) AND LOCKPIN (20) TO BE $.032^{+.016}_{-.005}$ WITH ROLLER AND LOCKPIN NOT IN CONTACT, MAX. GAP BETWEEN ROLLER AND LOCKPIN TO BE .018 SEE DETAIL—B

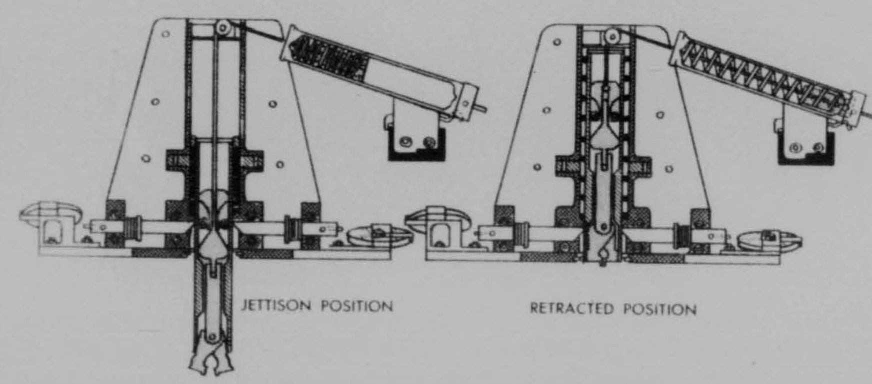


Figure 3—5. Forward Rocket Post Assembly

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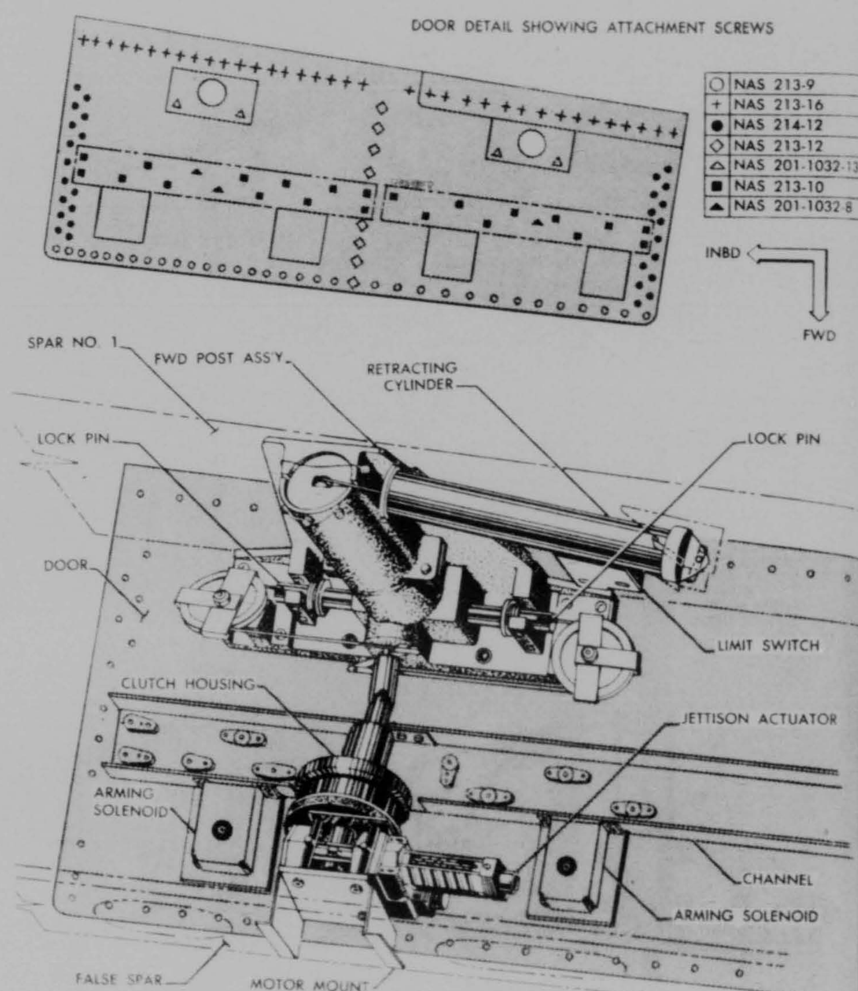

Figure 3–6. Forward Rocket Post Installation (Left Wing).

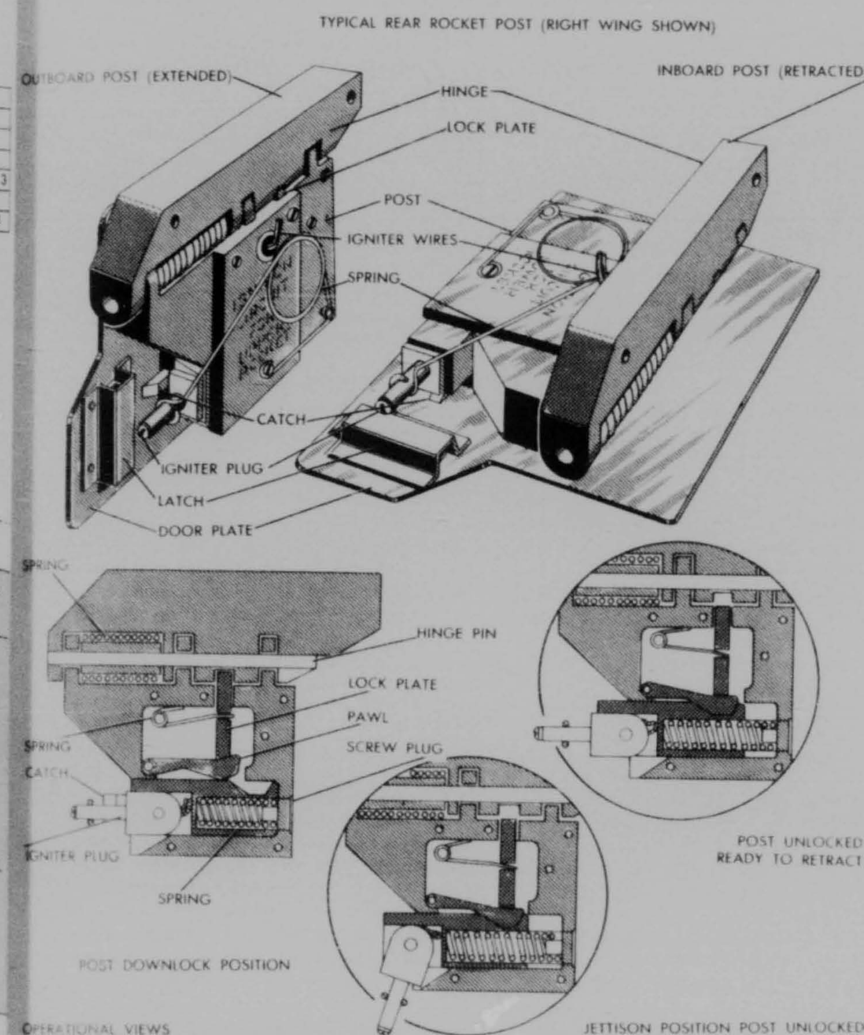

Figure 3–7. Operational Views.

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diameter or fore-and-aft dimension of 1.5 inches, must receive the support pin of the rocket-lug band and must be capable of withstanding the full vertical loads, the forward shear-wire load, and the aft air and acceleration loads imposed on the rocket in ground and air maneuvering (Figures 3-5 and 3-6). At the rear, the rocket is supported by sockets in the aft extremities of the two uppermost fins which receive the rear pivotal support plugs. These plugs, mounted on small fittings which retract, after rocket firing or jettisoning, into the under surface of the wing or fuselage, contain a central insulated contact and an outer shell which is positively grounded to the airplane frame. Thus these rear mounting plugs provide both support and electrical connections to the rocket. Since the rocket is not completely constrained in a lateral plane by the front lug band, but is free to rotate about the lug-band pin as a center, twisting moments arising from side loads must be absorbed by the two rear support plugs. Also, the rear supports are required to bear a portion of the vertical loads imposed by the rockets, if the lug band is not positioned exactly at the rocket center of gravity. During jettisoning, the lug band is released from the front post and the rocket swings downward, pivoting about the rear support plug, quickly developing sufficient centrifugal force to move away from the rear support plugs. Hence, these rear plugs must be capable of pivoting downward from their normal horizontal position. Normally, they are retained in their horizontal or firing position by a strong spring, or detent, or by a shear wire (.064-inch diameter standard bomb-arming wire) to prevent their moving about during loading of the rockets. The rear must be capable of being extended to the firing position and locked prior to loading without the use of loose parts or special tools. Upon firing or jettisoning of the rockets, the mounts retract automatically to their flush positions (Figure 3-7). The four rocket-stabilizing fins form a portion of both the launching and ignition systems. Identical sockets are incorporated in the outward rear corners of each of the fins. These sockets slide onto the rear support plugs to provide rear suspension for the rockets. They also contain insulated, spring-loaded, contact pins which provide electrical circuits from the airplane support plugs engaged in the two upper fins to similar sockets in the two lower fins. The fin sockets are internally-wired to diagonally opposite fin sockets so that selective fin positioning on the aircraft launchers is not required. A single steel-lug band, incorporating a rearward protruding support pin at its upper edge, is located near the center of gravity of the rocket. The horizontal $\frac{3}{8}$-inch diameter support pin, engaging in a hole in the lower end of the retractable front post, provides the forward rocket support. The pin is designed to protrude behind the front post when fully inserted and exposes a horizontal shear-wire hole through the pin just aft of the post. A suitable shear wire (.102-inch diameter hard brass) is soldered at one end to the lug-band pin block and is easily removed for insertion into the shear wire hole after loading the rocket on the launcher. The lug band is clamped tightly about the rocket at the proper rear support plug-to-front post dimension and prevents movement of the rocket on the launcher. The rockets are fired electrically by the pilot through the bombing button on top of the control stick in a sequence and interval determined by a rocket firing control box or intervalometer. The rocket nose fuses are controlled by arming solenoids located inside the wing skin just forward of the front posts, or inside the posts themselves. The solenoids are controlled by a fuse-selecting switch located in the cockpit.

3. ROCKET LOADING

The retractable-post rocket launcher incorporates shortened mounts and improved sway bracing. Previous mounts were generally $\frac{1}{2}$ inch to 1 inch longer and sway brace points of the standard 5-inch HVAR lug band are spaced $2\frac{1}{4}$ inches apart. With the flush-mount launcher, the top rocket is suspended closer to the wind and fin sockets, by which the rear of the rocket is suspended. The rockets are spaced 10.34 inches apart. This improved mounting lends itself well to the double-shot or tier method of carrying rockets. In this arrangement, one rocket is suspended from the launcher mounts as described in the preceding paragraph and another round, staggered forward of the upper round slightly, is suspended from, and parallel to, the upper round. Identical fins and lug bands are used on both rounds. The lug-band pin for the lower round engages in a block attached beneath the upper round lug band and is secured by means of a shear wire. Fins of the lower rocket interlock at the rear with fins of the upper rocket to complete the support of the lower round.

Prior to loading the rocket, the front post and rear mounts are extended and locked. The rocket, with the front lug-band correctly spaced and tightly clamped, is raised and the lug-band pin inserted into the hole at the lower end of the inboard front post. As the projectile is slid rearward on the front post, the upper-fin sockets are guided onto the rear-support plugs and engaged simultaneously. After determining that the lug-band pin is fully engaged and that the rear support plugs are bottomed in the fin sockets, the shear wire attached to the lug-band block is inserted immediately into the shear-wire hole and both ends bent down to prevent its loss in flight. If double-shot loading is used, another rocket, with different lug-band spacing to accommodate the fin and lug-band spacing of the upper round, is slid into position beneath the upper

Figure 3—8. Type A-2 Control Projector Release.

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rocket. The lug-band pin of the lower rocket is engaged in the block located beneath the upper lug band and notches in the upper and lower fins are interlocked and engaged to provide rear support for the lower round. After ascertaining that the lug-band pin and both fin slots are fully engaged, the shear wire is removed from the lower rocket lug-band block, inserted through the shear-wire hole in the pin, and both ends bent down.

If air-arming nose fuses, MK 149, are used on the 5-inch HVAR, .064-inch diameter standard bomb-arming wires are to be inserted in the fuse as noted on the fuse tag, the arming wire swivel loops are inserted into the arming solenoids, and the wires cut to length.

Just before take-off, the rocket igniter plugs from the rockets are inserted into the proper fin sockets of the upper round as shown on the fin "decals." The upper round is plugged into the left socket, the lower round into the right socket of lower fins of the upper round (looking forward). It is imperative that these wiring connections be observed, since all aircraft designed with this type of launcher are to be wired to provide successful firing circuits in this order. Improper connection will result in the upper round firing first, with the lower round attached. The thrust line of the top round, being located considerably above the combined center of gravity of the two rounds, produces a large over-turning movement and results in a sharply curved downward flight of the two rockets and possible damage to the aircraft.

4. ROCKET FIRING

To fire the rockets, the pilot must turn the projector release control or intervalometer selector switch from **"off"** to **"single"** or **"auto"** (Figure 3-8). If in **"single"** position, the intervalometer will fire one rocket each time the button is depressed, in the sequence established by the aircraft rocket wiring. If in **"auto"** position, rockets will be fired successively at 1/10-second intervals as long as the firing button is held depressed. Upon depressing the firing button, a rocket-firing circuit is energized to ignite an electric squib inside the rocket. This in turn ignites the rocket propellent. A forward thrust is produced which results in shearing the rocket retaining shear wire and the rocket is launched from the airplane. If both nose- and base-fuses are used in the rocket head, before firing the rockets the pilot selects which fuse shall function on impact by placing the fuse-arming selector switch in the **"inst"** or **"delay"** position. When the switch is in **"inst"** position, the fuse-arming solenoids are energized and retain the nose-fuse arming wires, allowing the nose fuses to arm upon firing of the rockets and producing instantaneous detonation upon impact. When the switch is placed in the **"delay"** position, the arming solenoids are not energized, the nose-fuse arming wires are released with the rockets and the nose fuses fail to arm, thereby allowing the base fuse (.015 second delay) to function on impact (Figure 3-9). Since the base fuse is armed by motor pressure during rocket burning, the rockets can be jettisoned in the **"safe"** condition if the nose-arming fuse wires are released with the rockets (arming selector switch in **"delay"**). (Figure 3-10).

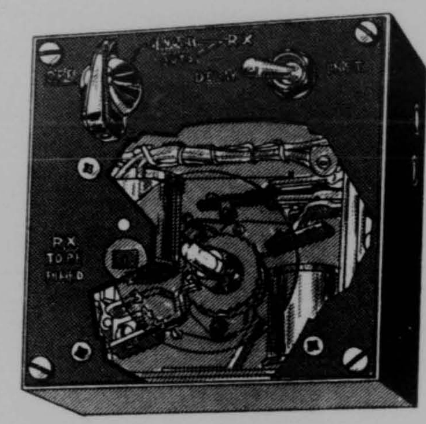


Figure 3—9. Type A-2 Control; Projector Release.

5. ELECTRICAL EQUIPMENT

The Type A-2 Projector Release Control, Specification No. 24973 (Figure 3-8), contains

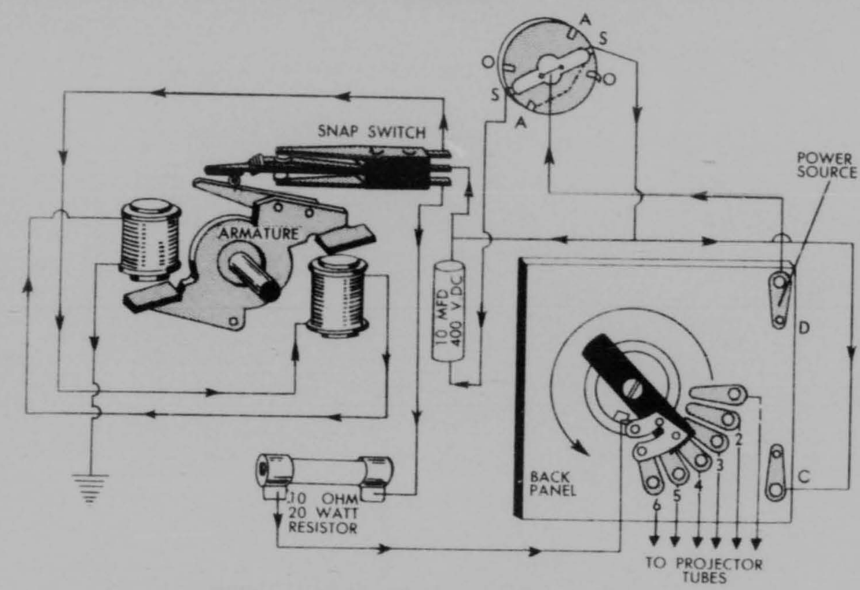


Figure 3—10. Cutaway View—Control; Projector Release.

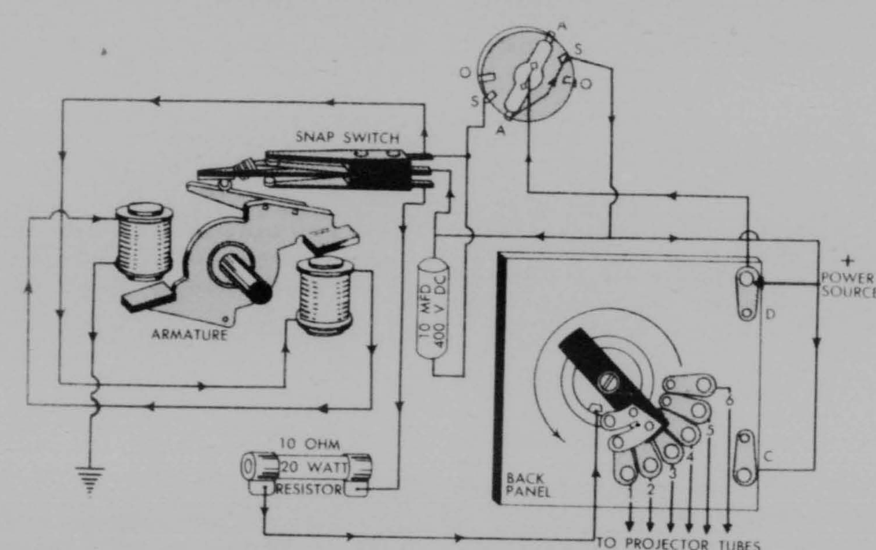


Figure 3—11. Schematic Diagram—Single Actuation.

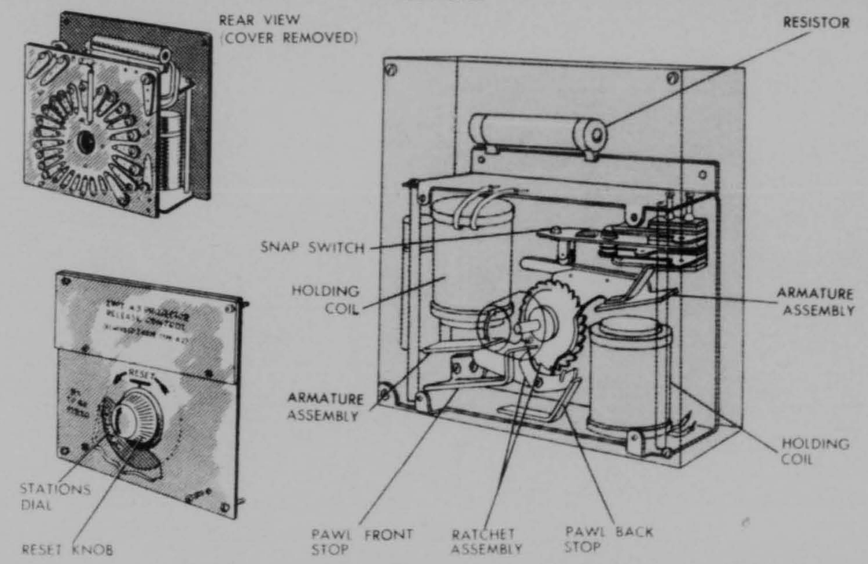


Figure 3—12. Schematic Diagram—Automatic Actuation.

a 24-volt, timed-relay stepper or intervalometer which provides electrical circuits to successive rockets (Figure 3-11). When actuated by the bomb-release button atop the control stick, the control will deliver to the rocket circuit indicated in the circular window on the control panel dial, a firing impulse each time the button is depressed (selector switch in **"single"** position) or impulses in train or ripple at the rate of one every 1/10 second as long as the button remains depressed (selector switch in **"auto"** position). The **"inst—delay"** fuse-arming selector switch located at the upper right of the control box panel will energize all arming solenoids simultaneously when in the **"inst"** position. The electrical supply for this circuit must be adequately protected by a circuit breaker of a size determined by the total number of AN-A-2 arming solenoids employed in the installation (Figure 3-12). The ANA-2 solenoid requires .25 to .50 amperes of 28 volts. The Type A-2 control is housed in a metal box 4¼" x 4¼" x 2¼" and has a total weight of 2.2 pounds. The control must be located adjacent to the pilot in such a position that he may readily set the dial indicator and switches on the panel. Its face must be visible without the pilot having to move from a normal sitting position, and must be easily operable by the hand which normally operates the engine-throttle control. The Type A-3 Projector Release Control, Specification No. 24975, is a modification of the Type A-2 in which the selector switch and fuse-arming switch have been removed and placed as shown on Drawing "Armament Control Panel", Air Force Drawing No. 4704432. Its operation is similar to that of the Type A-2 and its location requirements are identical. The wiring diagram for the Type A-3 control is shown on Air Force Drawing No. 45A5750. Its size is 4 11/16" x 3½" x 2½" and its weight is 1.5 pounds. The Type AN-A-2 Bomb Arming Control, 24-volt, is required, one for each rocket carried. Its weight is approximately .23 pound. It is located flush in the wing skin forward of the mounts, or in the mounts themselves. Care must be taken to provide housings around the solenoids and fairings about the slots to facilitate introduction and extraction of the arming-wire loop.

Aircraft Wiring

A single wire system with ground return is used between the cockpit control box and wing terminal strips for the front and rear launcher mounts. The wire must be No. 18 gauge or larger, adequately insulated, numbered, and supported throughout its length (according to Specification No. AN-J-C-48). From each of the rear support plugs, both hot and ground wires must be adequately protected from rocket blast, if exposed, and must lead to terminal blocks in each wing. Fuse-arming solenoids, when their support brackets are properly grounded, require only a single supply wire. All wire, terminals, and rear support plugs or their fittings must be properly and permanently numbered in accordance with wiring diagrams furnished. Rocket-firing circuits are wired and numbered, preferably in the following order; for number of rockets = n:

No. 1 Lower left outboard
No. 2 Lower right outboard
No. 3 Upper left outboard
No. 4 Upper right outboard
No. 5 Next inboard lower left
No. 6 Next inboard lower right
No. 7 Next inboard upper left
No. 8 Next inboard upper right
. . . .
. . . .
. . . .
No. n-3 Lower left inboard
No. n-2 Lower right inboard
No. n-1 Upper left inboard
No. n Upper right inboard

This method clears rockets from each launcher as soon as possible so that the airplane is maintained at its lowest drag configuration. The method also allows partial rocket loads to be carried and still be fired in uninterrupted sequence. It may be generally stated that a given number of rockets carried in double-shot, or two-per-launcher, will result in less total drag than the same number of rockets carried on individual launchers. That is, four rockets carried double on two launchers will result in less drag than four rockets loaded singly on four launchers.

Rocket Circuit Checking

Prior to each rocket-firing mission, a thorough ground check is required of the intervalometer, rocket-firing circuits, rocket fuse-arming circuits, and rocket-jettisoning circuits. If ground-safety cutout switches are incorporated in the rocket circuits, they must be capable of being overridden by a manual ground-check switch to enable the circuit checks to be made.

The jettisoning circuits are checked by extending the front posts and, individually or collectively, placing a screw driver, spare lug band, or other suitable pin through the lug-band-pin support tongs. If the jettison switch is operated in the cockpit while a downward load of approximately twenty-five pounds is exerted on the test pins, all pins should be released instantly.

Fuse-arming circuits can be checked by turning on the **battery switch, master armament switch,** if used, and the **fuse-arming switch** to **"inst"**. A click should be heard simultaneously from all arming solenoids as the solenoids are energized. Positive check of solenoid operation is made by attempting to insert a coin, screw driver, or arming-wire loop into the solenoid opening. If the plunger is properly extended by solenoid actuation, it will be impossible to insert the blade past the spring-loaded button. The fuse-arming switch should then be returned to the **"delay"** or **"off"** position.

Complete rocket-firing circuits can be checked only with rockets installed on all launchers, since the fins themselves incorporate a portion of the firing circuits. Before loading the rockets, a positive check must be made in the cockpit to insure that all switches are **"off."** Rocket loading should proceed from inboard to outboard on each wing to facilitate access to launchers and rockets. If double rounds are to be carried on each launcher, corresponding lower rockets should be mounted immediately after each upper rocket is installed and the shear wires inserted. All rockets loaded on aircraft prior to circuit checking must have their igniter plugs and cables completely enclosed inside the metal, cup-shaped, rear shipping cap which has been tapped into place in the nozzle shroud ring firmly enough to prevent its falling out during rocket handling and loading. **It is mandatory that this precaution be taken to prevent accidental insertion of a rocket igniter plug during the firing circuit check.** A tester, Electric Circuit, Type B-2, incorporating multiple-indicator light circuits is clipped to the wing trailing edge and the tester plugs inserted into the lower fin sockets of the upper rounds. If available, two tester units are used to allow checking of all rocket-firing circuits simultaneously. After the numbered tester plugs have been inserted into the corresponding firing circuits, the area fore and aft of the airplane must be cleared of personnel and the cockpit switches turned on to check rocket firing circuits. With the intervalometer in **"single"** position and the dial set to No. 1, the circuit-tester lights should indicate firing circuits available alternately at each wing, outboard to inboard, one indication each time the button atop the control stick is depressed. The intervalometer should then be set to **"auto"**, the dial returned to No. 1, and the firing button depressed, allowing the intervalometer to click around in "automatic" or "ripple" fire. All cockpit switches should then be turned off and the ground-safety override switch released to the normal or cutout condition. Shipping caps may be removed and igniter wired from the rockets clipped firmly behind the rockets and fins by means of the trailing edge metal tube. It is extremely important that any excess cable or "slack" be firmly positioned behind the rockets out of the airstream and rocket-blast region.

A rigid routine involving a minimum of personnel must be observed during all checking and plugging in operations to avoid confusion, delay, and accident. Before plugging in, the armorer should make visual check with the pilot to insure all rocket circuits are **"off."** The rockets are to be plugged in immediately prior to take-off only, and when the rockets are pointed toward a safe and uninhabited area. Plugging in commences at either outboard station and proceeds completely across all launcher stations, the armorer passing under the fuselage or around the nose after he plugs in the inboard position on one side and then proceeds to the inboard position of the opposite side. Plugging in should be accomplished at arm's length, the armorer standing well to one side of the rocket being plugged in, never standing or passing to the rear or front of any rocket previously plugged in. The igniter plug is inserted firmly as far as possible with the metal wings or finger tabs approximately 30 degrees counterclockwise from parallel to the rocket-fin blades, then twisted clockwise into locking grooves of sockets until the plug wings are parallel to the rocket-fin blades. If any doubt exists as to the plug being properly installed, a vigorous rearward pull on the plug (not the cable) will unseat the plug if it is not locked into place. The armorer, as he is plugging in the rockets, must again check to see that the lower round is being plugged into the right-fin socket and the upper round into the left-fin socket of the upper round. Immediately upon completion of the plugging in, the armorer gives the pilot a visual signal to that effect.

6. ROCKET JETTISONING

Provisions should be made in the front posts of these launchers for jettisoning the round by releasing the rocket lug band. Upon release of the forward end, the rocket swings downward and pivots about the rear support plugs as a pivot until the rocket slides off the plugs and falls free. The downward angle at which this release occurs is from 30 to 90 degrees, depending on the aircraft velocity at jettisoning. Hence, the rear support plug must be capable of a 90-degree swing downward from the normal launching position and should be spring-loaded upward so as to return to the launching or firing position before rear mount retraction is complete. To facilitate rocket loading, the rear support plugs should be held in the launching position by means of a shear pin or spring detent which will resist a 20- to 30-pound downward load at the forward tip of the plug.

The mechanism to accomplish jettisoning in the front posts must be as simple and foolproof as possible and incorporate a fine adjustment to compensate for wear and to facilitate maintenance. The jettisoning operation must involve no loss of parts and require no recurring repair to the launchers. Visual or mechanical means are provided to indicate the safe or "locked" position of the jettisoning mechanism prior to loading rockets. It is required that both front and rear mounts retract automatically after rocket jettisoning has been accomplished.

Jettisoning of the rockets is controlled electrically from the cockpit. Two methods for jettisoning are required in combination with similar emergency jettisoning or salvo of bombs and external fuel tanks. For ridding the aircraft or rockets, bombs, and fuel tanks in flight a "bomb-and-rocket-salvo" switch is provided in the cockpit, which, when operated, will result in the simultaneous actuation of all rocket, bomb, and external fuel-tank jettison or release circuits. To provide another important safety feature, it is possible to setup or preselect, prior to take-off, individual jettisoning or release circuits for rockets, bombs, and external fuel tanks so that the pilot at any time during the take-off may effect emergency release of all droppable armament and fuel loads by pressing the bomb button atop the control stick. Once the airplane has completed take-off, the various preselected circuits are switched off and the normal jettison or firing circuits employed thereafter.

If the rockets are mounted with their centerlines less than sixty inches above the ground level when the airplane is in taxiing or take-off attitude, a landing-gear cutout switch must be incorporated in the rocket jettisoning circuits to prevent possible damage to the aircraft. Such damage may result from the rockets swinging downward and striking the ground before the rocket fins have left the rear posts or from rockets ricocheting back up into the wings or flaps after falling free and striking the ground. If required, this switch interrupts the jettisoning circuits until the airplane has attained sufficient altitude to prevent such damage. Both firing and jettisoning circuits, if interrupted by a ground-safety switch, must include a manual, momentary "on" or "flagged" overriding switch for use in ground check of the circuits.

7. LOCATION OF MOUNTS

The launcher mounts are so positioned and of such length as to provide a minimum of ½-inch clearance to the lower wing or fuselage skin as the rocket moves forward along its flight path. A ¾-inch minimum clearance must be provided from the rocket head, motor and fins (in their firing position and along their flight paths), to the airplane flaps, control surfaces, landing gear and lights, external guns, bombs, fuel, smoke or chemical tanks or adjacent rockets.

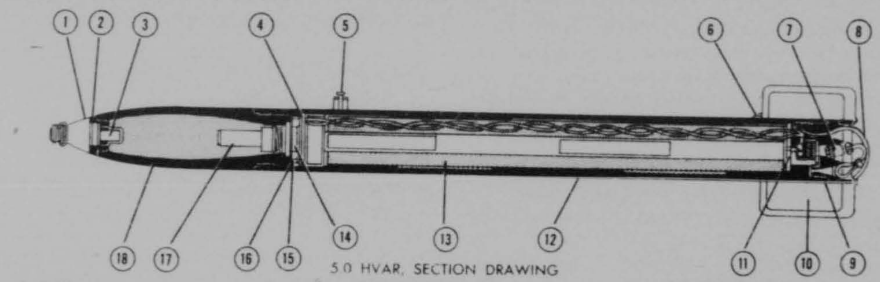
A minimum ground clearance of six inches is provided between the fins of the lowest rocket and the ground level under any combination or adjustment of rockets, any combination of airplane struts fully compressed and tires deflated, and any normal change in attitude during take-off. If the double-shot arrangement (tier launching) is prohibited at any mount by this restriction, "decals" or other permanent markings are used on the mount affected.

The rocket-fin-to-lug-band spacing is here defined as the distance, measured parallel to the rocket centerline, from the rear face of the lug-band block to the rear face of the fin sockets. The fore and aft spacing of the front and rear posts on the aircraft provide for a minimum fin-and-lug band spacing of 32 to 48 inches and the maximum dimension that can be used and not place the big band on the war head of the rocket. The distance between front and rear posts must be equal at all rocket stations within plus or minus .062 inch.

The centerlines of the rockets must be parallel to the line of flight or "velocity vector" within ± 1 degree under the following conditions: 85 per cent maximum speed 3250 feet standard-pressure altitude, normal crew, full ammunition and oil load, ½ fuel load, ½ external rocket load, no bombs.

Centerlines of the rockets and their respective front posts must be in the same planes, these planes to be parallel to each other and vertical, or perpendicular to the wing dihedral angle up to a maximum of 10 degrees to the vertical. At angles greater than 10 degrees from the vertical, binding and distortion may be encountered in the rear posts during jettisoning.

The rockets must not interfere with normal operation of the approved machine gun installation. Also, AMC approval must be obtained for any design in which the installation



1. FUZE
2. FUZE LINER ASSEMBLY
3. BOOSTER CUP
4. IGNITER
5. LUG BUTTON
6. SUSPENSION MOUNT
7. WIRE AND PLUG
8. REAR SEAL
9. NOZZLE SEAL
10. FIN
11. GRID
12. MOTOR TUBE
13. PROPELLANT GRAIN
14. FRONT SEAL
15. FELT SEAL
16. FIBER SEAL
17. BASE FUSE
18. BODY

Figure 3—13. Projector Release Control.

of a full complement of rockets results in displacement or interference with the normal use of other external stores such as bombs and fuel tanks.

8. ROCKET BLAST PRESSURES

Only meager information is available concerning the magnitude and extent of the blast pressures surrounding rockets when fired from aircraft in flight. The following information was obtained from ground firing experiments by launching 5-inch HVAR at 70 degrees from aircraft wing launchers:

Peak positive (away from rocket centerline) pressure normal to a wing surface six inches above rocket centerline at various lateral distances from the vertical plane through the rocket fired:

Lateral distance in feet	0	1	2	3	4
Pressure in lbs./sq. inch	15	10	5.2	3.5	Negligible

Peak negative (toward rocket centerline) pressures occurring during rocket firing are approximately 1/4 to 1/3 the above positive pressures.

The duration of periodic pressure fluctuations appears to be on the order of 30 milliseconds and pressure fluctuations are principally of 420 C.P.S. frequency.

9. BLAST PROTECTION

The airplane skin, structure, and control surfaces in areas adjacent to the path of the rocket blast must be capable of withstanding repeated rocket firings without sustaining immediate or progressive failure. (See AF Specification No. 34014, Gun and Rocket Installation; Engineering Armament Acceptance Test of.) Tests must be conducted to determine blast resistance under any of the conditions listed below. All blast firing tests are made with full-scale installations on actual airplane structures and by firing such rocket projectiles as are being considered for the installation at their upper temperature limits. Test results must be submitted to, or obtained by, the AMC before approval can be given for any of the following installations:

Rockets are mounted with their centerlines less than eight inches from conventional metal skin-and stiffener wing structure. (Areas offering inadequate blast resistance must be reinforced by increasing the skin thickness and/or internal supporting structure.)

Rockets mounted with their centerlines (extended) less than twenty-four inches from any fabric covered wing, fuselage, or control surfaces, until extensive tests have been conducted and test results submitted and approved.

Rockets mounted under or forward of any aileron or other control surfaces, until adequate ground, flight, and air firing tests have been conducted and approved by the AMC for production installations.

10. ROCKET PROJECTILES

Two types of rocket projectiles are to be considered in the design of flush-mount launchers, the 5-inch HVAR and the 5-inch T-200 rocket. Both rockets are equipped with T-38 Modification Kit—Rocket Aircraft 5-inch, which consists mainly of the flush-mount-type fin assembly and lug band as described above in paragraphs 3 and 4. The rockets generally consist of three main components (Figure 3-13). In the H.E., or armor piercing head, the motor contains the propellent and the venturi nozzles. The fin assembly of four fins is spaced 90 degrees apart and clamped about the aft end of the rocket. A high-speed jet issues rearward from the burning propellent and a forward thrust forces the projectile forward, shearing the retaining wire and propelling the rocket along its trajectory. Pertinent data for the two applicable rockets are:

		TENTATIVE
Designation	5-inch HVAR	5-inch T-200
Drawing No.	H25013294	48A4262
Weight of round	140 pounds	170 pounds
Overall length	69 inches	120 inches
Motor diameter	5 inches	5 inches
Fin circle diameter	15.75 inches	15.75 inches
C.G. from nose	34.5 inches	50.0 inches

Due to the increase in length and extreme shift in center of gravity of the T-200 as compared to the standard rocket, 5-inch HVAR, it is not considered feasible to carry the T-200 rocket in the double-shot or tier arrangement.

The mass flow, which is indicative of the exhaust blast pressures of the T-200 rocket, is approximately 20 per cent less than that of the 5-inch HVAR.

11. STRUCTURAL REQUIREMENTS

The strength of the rocket mounts and their supporting structure is governed by the weight and mounting dimensions of the various combinations of rockets employed. The installation is investigated for all three conditions of loading, one 5-inch HVAR, double-shot (two) 5-inch HVAR, and one T-200 rocket per launcher. The installation is designed for the following conditions:

Vertical Loads. Front and rear mounts, and the structure to which they are attached, are designed for the maximum ultimate vertical-load factors, positive and negative, of the airplane. These loads are assumed to act at the combined center of gravity of the single and double rounds, the resultant loads being distributed proportionately to the front and rear mounts:

Fore, Aft and Side Loads. The mounts are designed to withstand an ultimate side-load factor of 2.25 and an ultimate fore and aft load of 3 acting at the combined center of gravity of the double rounds.

Release Load. In addition to the above loads, but not acting simultaneously with them, a design release load of 2,000 pounds acting forward at the upper lug-band support pin must be sustained by the front post in its extended or firing position due to the required force for shearing the retaining wire upon launching of the rocket.

12. JETTISONING CONDITIONS

The pilot must be capable of jettisoning rockets electrically from all stations simultaneously under the following flight conditions:

2 "G" pullout.

Level flight at cruising speed.

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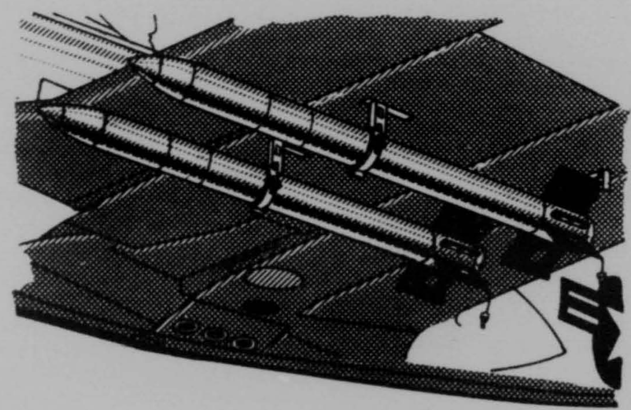
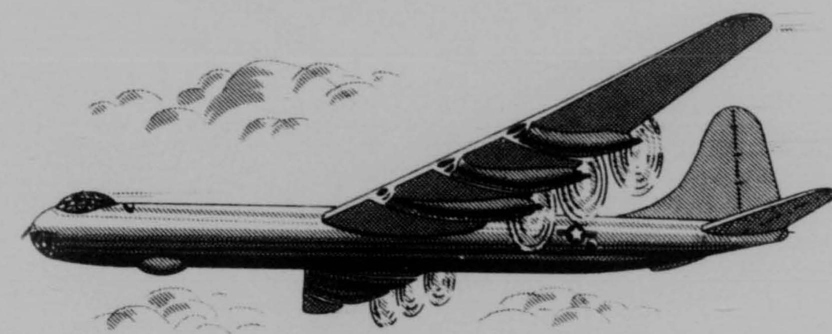


CHAPTER 4—BOMBING ACCESSORIES



SECTION I—BOMBING SYSTEM UNITS

1. INTRODUCTION

There is no question as to the most effective method of pouring destruction into an enemy's industry, supply points, transportation systems, and other points vital to his pursuance of offensive or defensive action. The "winged artillery" or bombing aircraft clearly does everything that ground artillery can do, except that it can operate over vastly greater areas with more highly concentrated effect.

The United States Air Forces first airplane, a Wright Flyer, wasn't capable of carrying and dropping our smallest present-day bombs. The total weight of bombs dropped on London during World War I by the German Zeppelins and Gothas did not equal that carried by four fully-loaded B-29 Superfortresses. Early efforts at aerial bombing were crude. Early bombing efforts consisted of tossing out five-gallon cans filled with explosives and fused by an ordinary wick-type fuse, throwing out steel darts, and ordinary artillery shells. Gradually, however, the pear-shaped and streamlined bombs equipped with mechanical fuses and vane-type fins were developed. As the aircraft and bombs were improved, brackets or supports for carrying these bombs on the airplane's wings and fuselage had to be developed. In the planning and experimental stages, certain characteristics of bombing systems were desired. Engineers, in designing these systems, worked on the basis that the bomb load should be carried safely, considering such factors as stress and strain on the airplane, and prevention of arming until dropped or released.

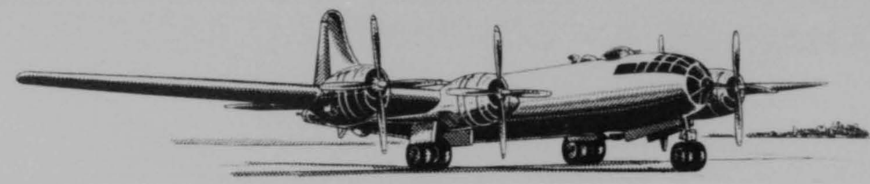
Another obvious requirement was that there should be complete and flexible control over the release of the bombs, in that they might be dropped singly or in groups (sticks or trains) with a preselected interval between each bomb.

In emergencies such as take-off trouble or crash landings, it was necessary to have a means of dumping or jettisoning the entire bomb load in an unarmed or "safe" condition.

2. BOMB TRAINS AND CONTROL OF BOMB RELEASE

General

A bombing system is predicated on the "bomb train" or group. This is essentially a



group of bomb-rack release units mounted on one or more bomb racks. These release units, in one group or in train, are connected electrically in series much as beads are strung. A release impulse is sent to a bomb train and the first bomb is released. To release subsequent bombs the impulses must enter the first release unit to reach the second; then it must enter the first, and then the second release unit to reach the third, and so forth. Usually one entire bomb train will be located on a single bomb rack, and there will be two or more separate bomb trains and consequently two or more separate bomb racks in an aircraft. However, early model North American Mitchell bombers had only a single bomb train while the Boeing Superfortresses use four bomb trains divided, on occasion, between as many as twelve separate bomb racks.

Rack Selector Relay

Since the balance point (center of gravity) of an airplane is in the area of attachment of the wings to the fuselage (wing root), designers of bombing planes attempt to distribute the bomb load evenly within this area. After loading the bombs they must be released or dropped in an even distribution from the various bomb racks in order to maintain balanced flight characteristics. A unit which automatically distributes the bomb-release impulse between bomb racks is the "rack selector relay."

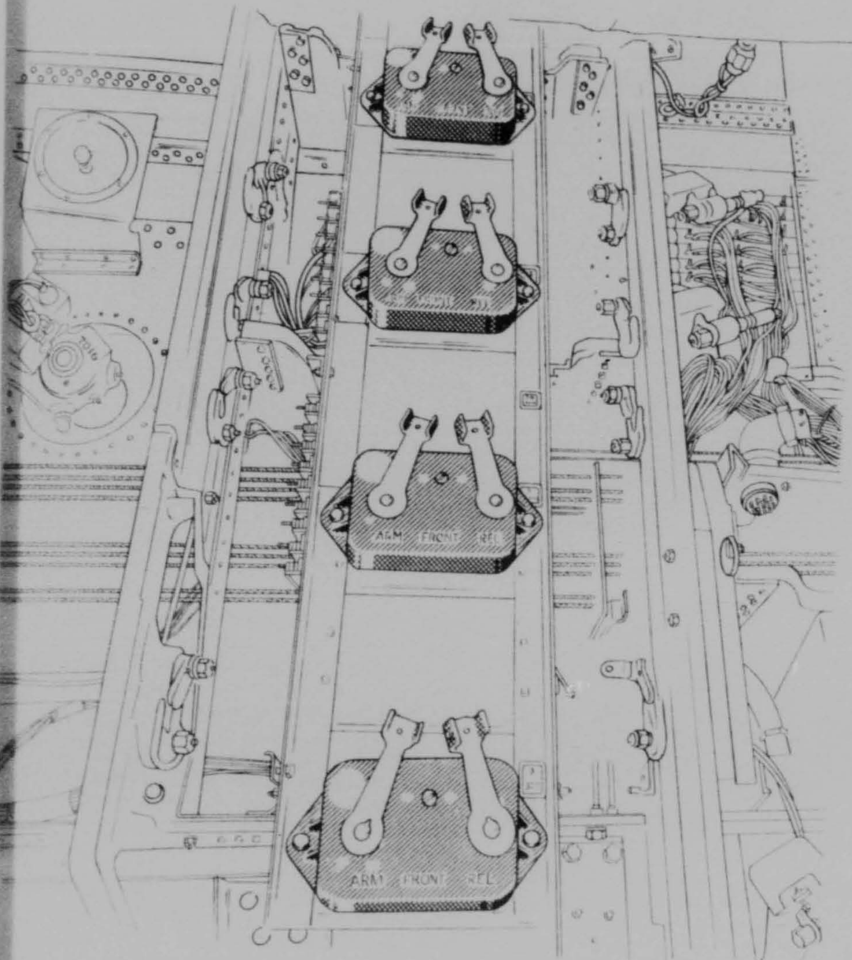
Interval Control Unit

The unit used to control the number of bombs released with each bomb-release impulse, and the interval spacing between each of the bombs so released is generally called a "bomb-release interval-control unit" or "intervalometer." Although there are two principal types of these, the function of both is essentially the same. This unit delivers the bomb-release impulses to the rack selector relays. These in turn distribute the impulses evenly between the various bomb trains or groups. The bomb-release impulse is initiated by closure of the bombardier's bomb-release switch.

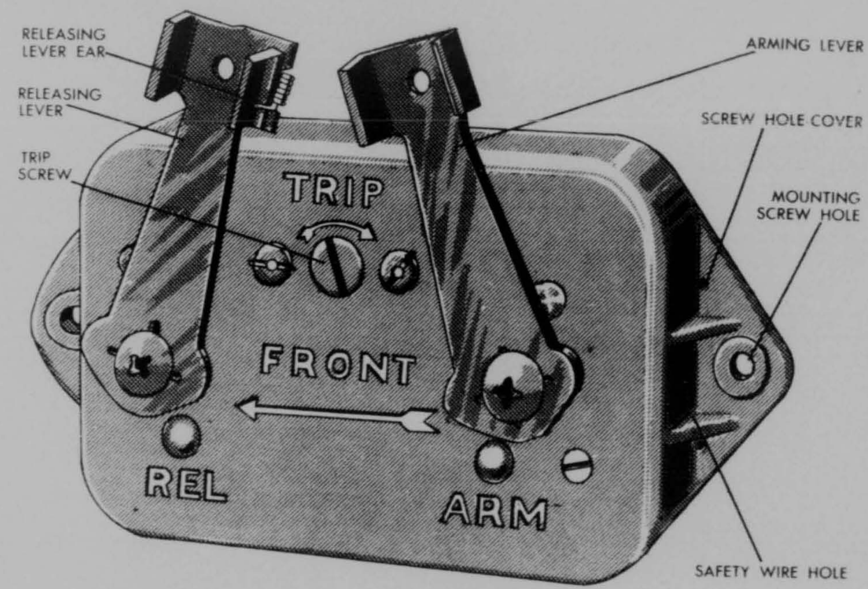
3. DESCRIPTION OF BOMBING SYSTEM UNITS AND SYSTEM OPERATION

General

Bomb racks are of two general types: internal and external, so designated from the manner in which they are carried by the airplane. Racks which are attached to the outside of the fuselage or to the underside of the wings of an airplane are known as "external bomb racks." Those which are attached to the inside of the fuselage and which carry the bombs entirely within a compartment in the fuselage are known as "internal bomb racks." Bomb racks are further classified as to type or model and carrying capacity. In order that the operation of releasing a bomb, and the consequent sudden decrease in load, may not disturb the steady horizontal flight of the airplane, the center of gravity of each bomb of the bomb load must be as close to the center of gravity of the airplane as possible. With an internal rack, this condition may be satisfactorily obtained since the distance of the bombs from the center line of the fuselage is not great when compared with the distance to the control surfaces of the wings. The center of gravity of the various sizes of bombs does not differ materially, and it is therefore possible to locate the bomb rack correctly in relation to the fore and aft center of gravity of the airplane. When some types of external racks are mounted on the wings, the balance of the aircraft is not always easy to retain.



SECTION II—BOMB RACKS

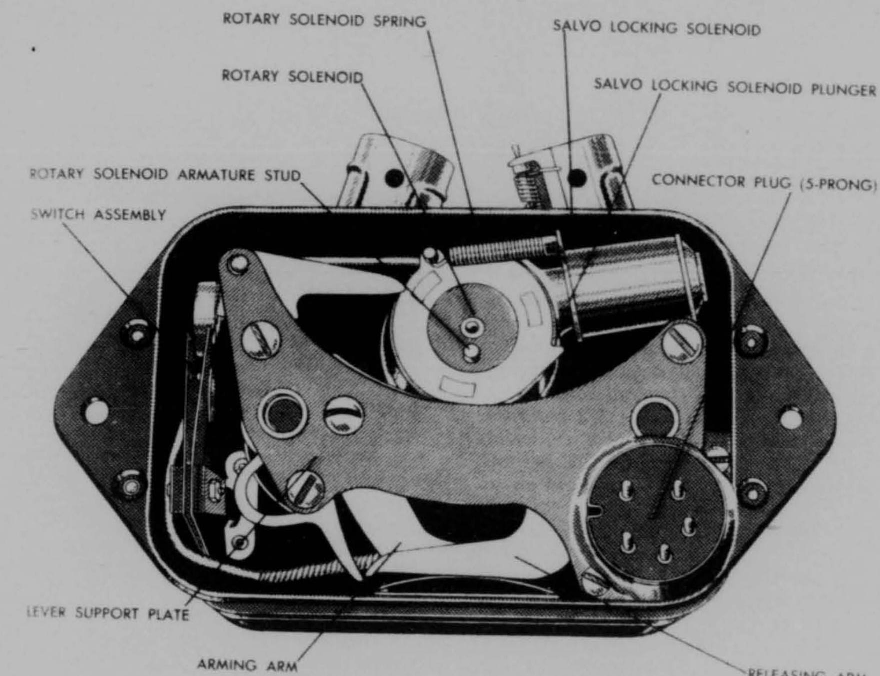


1. BOMB-RACK RELEASE UNITS

Bomb-rack release units (usually called "releases") are of two types: The first, type A-4, is used on all electrical bomb-release systems; it is being replaced by the second, type A-5, because the bombs are salvoed when the indicator lights are turned on and the bomb-release switch is pressed.

2. THE A-5 BOMB-RACK RELEASE UNIT

The component parts include an arming lever and a release lever, a rotary solenoid to trip the levers, a salvo-locking solenoid for dropping bombs unarmed, a releasing arm, an arming arm, a combination transfer and indicator light switch, a switch operating arm, a shock plate, a trip screw, and internal wiring terminating in a five-prong electric plug. All parts are assembled in a die-cast aluminum case with a dustproof cover for the back. A drilled flange at either end of the case permits bolting the unit to the rack. The five-prong plug connects with a socket on the bomb rack to provide an electrical connection. The release lever is provided with a hinged ear to facilitate local manual release which may be accomplished by prying the release lever of the shackle out of engagement with the release lever of the release unit, dropping the bomb "safe". A slotted manual trip screw, located on the face of the release unit, provides for local manual release. Bombs dropped by this means are in an armed condition, and the internal switches are moved into the same position they would have assumed if the release had been actuated in the normal manner. If the release is tripped manually, the trip screw should always be returned to its original position, or it will be impossible to cock the release. Closing the "salvo" switch energizes the rotary solenoid and the salvo's solenoid, causing the release lever to fall and



the arming lever to remain cocked. Bombs released in this manner will fall "safe". In operation, the bomb release impulse enters the release unit through electrical pin No. 2 and energizes the rotary solenoid. Then the rotary solenoid is energized, the solenoid armature plate rotates, disengaging the solenoid armature stud from the releasing arm and the arming arm. The releasing arm is disengaged slightly ahead of the arming arm. The above action causes the arming lever and the release lever to be tripped, resulting in the bomb being dropped in an armed condition. After the release has been tripped and the electrical impulse terminated, action of the switch operating arm causes the internal switching arrangement to assume a position that will close the circuit to the next unit. The rotary solenoid returns to its normal position, and the circuit to the indicator light and salvo solenoid is opened. One cycle of electrical operation has been completed. Manual operation is accomplished by turning the trip screw on the front of the release in the direction indicated. Function of the release is exactly the same as described for electrical release. When the salvo switch is closed, the rotary solenoid and the salvo solenoid are energized. Energizing the salvo solenoid causes the salvo-locking solenoid plunger to be thrust outward in a position to oppose the movement of the rotary solenoid at the point where the arming arm would be tripped. As the rotary solenoid is activated, the releasing arm is disengaged from the rotary solenoid armature stud, allowing the release lever to trip. Since further rotation of the rotary solenoid is prevented by the action of the salvo-locking solenoid plunger, the arming arm maintains engagement with the rotary solenoid armature stud and the bomb is dropped in the "safe" condition.

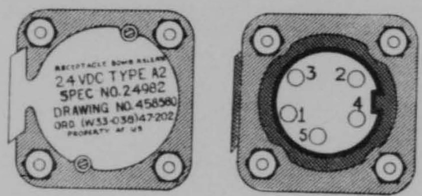


Figure 4–1. Receptacle Bomb Release Type A2.

3. BOMB RELEASE UNIT RECEPTACLES

Bolted to the bomb racks at each bomb station is a "bomb release unit receptacle" which serves the bomb-rack release unit in the same manner that a wall plug does on an electrical home appliance. The standard receptacle at present is the type A-2. The A-2 receptacle has five socket terminals which are legibly marked 1, 2, 3, 4 and 5 (Figure 4-1). Between terminals 2 and 3 there is a contact switch which is normally closed when there is no bomb release plugged into the receptacle. The contact switch between terminals 2 and 3 is a "skip-over" switch which permits current to flow to the next station if a bomb release is not installed in the receptacle. The installation of a bomb release at the receptacle allows the contacts between terminals 2 and 3 to be broken by the action of the prongs pushing against the spring assembly. Breaking this contact does not permit any current to flow from terminal 2 of the receptacle to the next station, unless the installed bomb release is tripped. The contact of the "skip-over" switch remains unbroken when there is no release installed, allowing current entering terminal 2 to be short-circuited to terminal 3 and flow to the next station.

4. BOMB SHACKLES

The bomb shackles act as links between the bomb and the bomb rack. These are provided in a variety of types for use with a variety of bomb sizes. Since the principle of operation of most bomb shackles is the same, the type B-7 bomb shackle (Figure 4-2) will be discussed in detail as representative of all types. The B-7 shackle (Figure 4-3) consists of a frame (provided with two carrying loops at

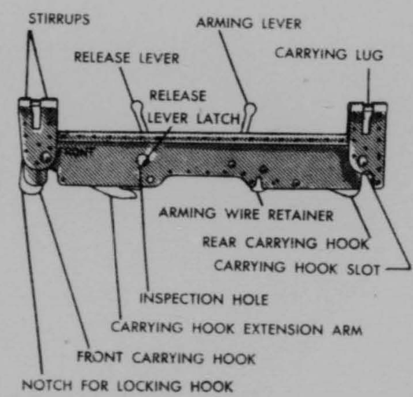


Figure 4–2. Bomb Shackle B-7.

the top for attachment to the shackle-carrying hooks of the bomb rack), carrying, releasing, and arming mechanisms. Two carrying hooks, pivoted in the lower part of the frame and spaced to engage the carrying lugs of the demolition bombs, are connected at their upper ends by the carrying-hook link. Attached to the carrying-hook link, near the front, is the sear. The latch mounted inside the front provides an engaging surface for the sear and trigger. The latch, pivoted at one end with a pin, is free to move up and down at the other end. With the sear engaged with a latch, the trigger is mounted in a position to engage the latch and prevent it from moving down to disengage the sear. The latch spring, positioned below the latch, moves the latch up in position for engagement of the trigger. The trigger arm projects through a slot in the top of the link and is positioned between the lugs of the tripping lever on the bomb rack. The trigger spring holds the trigger engaged with the latch. To close the

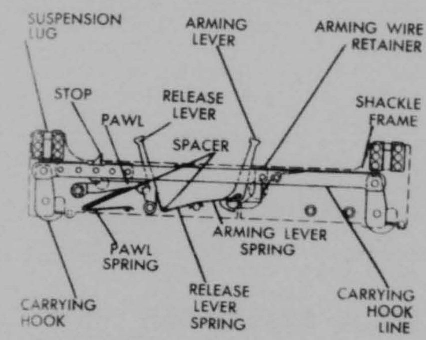


Figure 4–3. Detail of Bomb Shackle Type B-7.

carrying hook: as the link is moved forward, the latch moves up to engage the sear; the trigger then engages the latch, preventing the latch from being disengaged from the sear. Bomb release is accomplished by moving the trigger arm to the rear. Near the pin that positions the trigger to the frame is an engaging surface. As the trigger arm is moved to the rear to clear the latch, the weight of the bomb on the carrying hooks forces the sear (which is attached to the carrying-hook link) and latch to disengage, permitting the carrying hooks to open. The arming mechanism consists of the arming-wire retainer (pivoted in the carrying-hook link and held in position to retain the arming wire by a spring) and the arming hook. This mechanism is located inside the frame to the rear of the trigger. The arming hook is pivoted on the opposite side of the arming-wire slot from the arming-wire retainer. The arming-hook assembly has a hook at the lower end and an arm at the upper end. The arm extends through an elongated slot in the carrying-hook link, and is positioned between the lugs of the arming lever of the bomb release. The arming hook is held in the safe position by the arming-hook spring. The loop of the arming wire is placed in the slot above the retainer. When a bomb is dropped "safe", only the release lever is tripped. As the trigger is moved to release the carrying-hook link, the arming-wire loop and the wire fall with the bomb. To drop the bomb "armed" the release lever and the arming lever are

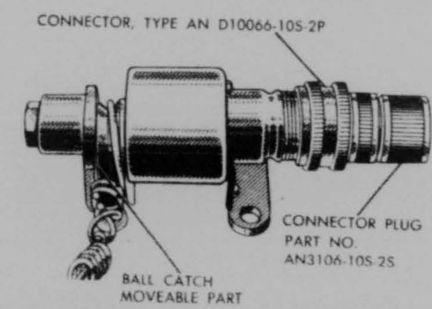


Figure 4–4. AN-A2 Bomb Arming Control Unit.

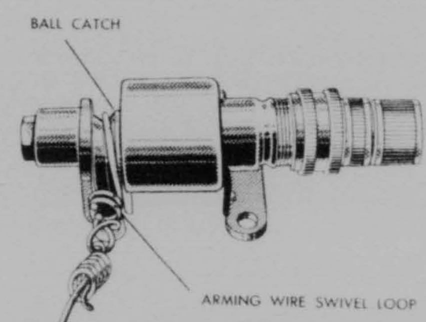


Figure 4–5. AN-A2 Bomb Arming Control Unit.

tripped. Tripping the arming lever moves the arm of the arming hook forward (by action of the arming lever of the release), and the arming hook is pivoted to the rear through the loop of the arming wire and under the retainer. When the bomb is released, the retainer moves to the rear as before, but the arming hook holds the arming wire in the shackle and prevents it from falling with the bomb. The arming wire, being held by the shackle, pulls the wire from the fuse and the bomb drops "armed".

5. BOMB ARMING CONTROL UNITS

The preferred arming unit is the A-2 (Figure 4-4). There is one of these arming units for each main bomb station, with the entire group of units electrically connected in parallel to each other. A bomb-arming control switch on the bombardier's control panel turns all these units on or off simultaneously. One of the bomb arming wire swivel loops (Figure 4-5) (always the nose fuse) is inserted into the arming-unit ball-catch. If the bomb is now dropped while the arming switch is "off," the arming-wire swivel loop simply pulls out of the ball-catch without arming the particular fuse controlled by that wire. However, if the bomb is dropped with the arming switch turned "on," the solenoid within the arming unit case is energized, locking the ball-catch. Therefore, the arming wire is held by the arming unit, and pulling out of the bomb fuse, arms the bomb. By use of the bomb-arming control system, the bombardier can not only select which bombs will be nose-armed but also whether or not the bombs will be released armed in salvo.

SECTION III — BOMBING SYSTEM CONTROLS AND INDICATORS

1. RACK SELECTOR RELAYS

The rack-selector relays (Figure 4-6) are needed when more than one bomb train or bomb group is used, as their purpose is to distribute the bomb-release impulses evenly between the bomb trains so as to maintain a balanced bomb load.

General

Each single-rack selector relay has two separate release circuits and can therefore operate two separate bomb trains, or bomb racks. Thus, four bomb trains would require two rack-selector relays, and six trains would require three rack-selector relays. Electrical connection is made to the bomb-rack selector by a nine-contact screw-type of pin, a female connector plug that is not furnished with this instrument. Electrical connections to the male connector plug should be as described in the paragraphs which follow.

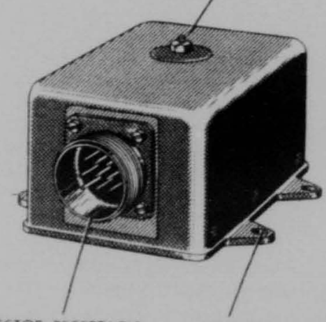


Figure 4–6. RS-2 Rack Selector.

Pin A is attached to a common circuit between all of the bomb-rack selectors in the circuit. It is not utilized if only one bomb rack selector is used.

Pin B is attached to the positive DC power source. A bomb group selector switch in this circuit will control output pin E.

Pin C is attached to the positive DC power source. A bomb-group selector switch in this circuit will control output pin F.

Pin D is the "impulse input" pin. It is attached to the bomb-release interval control or to pin H of the previous bomb-rack selector unit in the circuit.

Pin E is the first "impulse output" pin. It is attached to the desired bomb-rack release unit or series-wired group of release units.

Pin F is the second "impulse output" pin. It is attached to the desired bomb-rack release unit or group of release units.

Pin G is not used.

Pin H is attached to pin D of the next bomb-rack selector in the circuit. It is not used on the last bomb-rack selector in a circuit, nor when only one bomb-rack selector is in the circuit.

Pin J, electrical ground, is negative (—) and is made through the mounting bosses.

Function and Operation

Operation of the RS-2 rack selector is based upon a "feeler current" with the release impulses being transmitted to the group selector from the bomb-release control unit. This "feeler current" in reality is searching for a ground or path through which the circuit may be completed. When the circuit is completed through the cocked release, the proper relays in the selector close, thus providing a path for the firing impulse which releases the bomb after the firing button is depressed by the bombardier. The bomb-rack selector is an electrical device consisting of interconnected relays which will automatically transfer the bomb-release electrical impulse alternately between two circuits. Two bomb-release selectors, which are wired in series, will distribute the impulse between four circuits and three selectors, between six circuits, etc. Three bomb-rack selectors in series will transfer the bomb release impulse to circuits 1, 2, 3, 4, 5 and 6; 1, 2, 3, 4 and 5, and 1, 2, etc. Each circuit may be connected to any group of series-connected bomb-rack release mechanisms. The selector is so designed that if an output circuit from either pin E or pin F is not completed to ground (through an unreleased bomb-rack release mechanism), the circuit will automatically be excluded from the bomb "train". This allows uneven loading of bomb racks or bays, without any impulse failures in the bomb "train", and in each succeeding "train" which includes that bomb. By the inclusion of a manually operated bomb-group selector switch in each circuit, it is possible to direct the impulses into any one or more of the circuits the bombardier may desire. Should a bomb fail to release, the particular bomb rack should be excluded from succeeding bomb "trains" by means of the bomb-group selector switch, in order to eliminate an impulse failure in the train. After a "train" of bombs has been released, the first impulse in the next "train" may be directed into circuit number 1 (or the first closed bomb-group selector switch) by momentarily breaking the positive AC power source to all bomb release controls by closing the bomb-bay doors. Many different circuit combinations are possible in which RS-2 rack selector may be connected into the electrical bomb-release circuit. Each circuit has certain peculiarities which affect the operation and the sequence of release of the rack selectors. In general, the following procedure should be observed in order to insure proper release order: The first bomb-release interval-control impulse is sent to the first circuit in which the bomb-group selector switch is closed, and the second impulse to the second circuit, and so forth.

All bomb-group selector switches are thrown to the "off" position when cocking the bomb-shackle release mechanism.

Bomb-bay doors must be closed after the bomb-shackle release mechanisms have been cocked and bombs have been loaded.

Bomb-group selector switches to the circuit in which the release of bombs is desired are closed.

Bomb-bay doors are opened.

Bomb-release switch (bomb-sight or control switch in bomb-release interval-control circuit) are closed when in proper position to hit target.

Bomb-bay doors are closed after "train" of bombs has been released.

2. BOMB RELEASE INTERVAL CONTROL UNIT

General

The bomb-release interval-control unit (Figure 4-7) or "intervalometer" is mounted on the bombardier's control panel in most airplanes. These units employ relays and capacitors in controlling the interval between release impulses.

Train Selector Switch

The "train selector" switch is a two-posi-

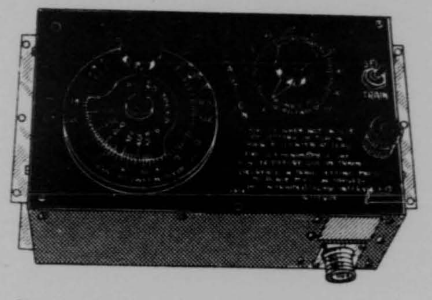


Figure 4–7. Bomb Interval Control.

tion toggle switch, located above the pilot light. When the toggle switch is in the "select" position, bombs may be released one at a time by depressing the bomb-release switch once for each bomb dropped. When the switch is in the train position, bombs may be released "in train" by depressing the bomb release switch once.

Counter Switch

The "counter" switch controls a number of bombs to be released in train. The dial is graduated from "0" to "50". The desired number of bombs to be released in train must be selected before the bomb release switch is closed. When the control dial reaches the "0" position, the release of bombs is stopped automatically due to the action of an internal switch arrangement. If, however, the selector switch is in the "select" position, bombs may be released after the dial reaches "0" by continuing to close the firing switch. It is possible to interrupt the "train release" of bombs at any time by manually turning the counter dial back to the "0" position. It is also possible to drop more than the selected number of bombs, or more than 50 bombs, by manually retaining the dial at any position above "0".

Interval Selector Dial

The interval selector dial indicates the distance in feet between the bombs on impact. The dial is operated by a knob at the bottom of the dial. Twenty-one settings are provided to enable the operator to select the desired spacing of bombs at the desired ground speed.

Pilot Light

The pilot light is illuminated when the "select train" switch is in the "select" position. When the "select train" switch is at the "train" position, and the counter dial at "0", the pilot light will be out. Current will not pass through the bomb-release interval control.

Releasing Bombs "In Train"

In order to release bombs "in train", the procedure is as follows:

The "train selector" switch is set on "train".

At least one minute prior to operation of the instrument, the counter switch is placed at the desired number of bombs to be dropped in the train.

The "interval selector" dial is set at the position which will give the desired spacing between bombs at the ground speed at which the airplane is expected to be traveling when the "train" is released.

This instrument is ready for operation at this point. Other allied operations, such as opening the bomb-bay doors and turning on the rack-selector switches, must be performed before releasing any bombs. For dropping one bomb at a time the "train selector" switch is put on "sel" position.

3. BOMBING SYSTEM CONTROL AND SAFETY SWITCHES (Figure 4-8)

General

A bomb-release switch of the push-button style is used. On closure the switch sends a spurt of electricity into the A terminal of the bomb release interval control unit, which results in an impulse going out from this interval control and into the rack-selector relay. Bomb-release switches, in cases of light bombers, are located in the pilot's compartment, as well as in the bombardier's compartment. But in the larger bombers this switch is logically located close to the bombardier's control stand.

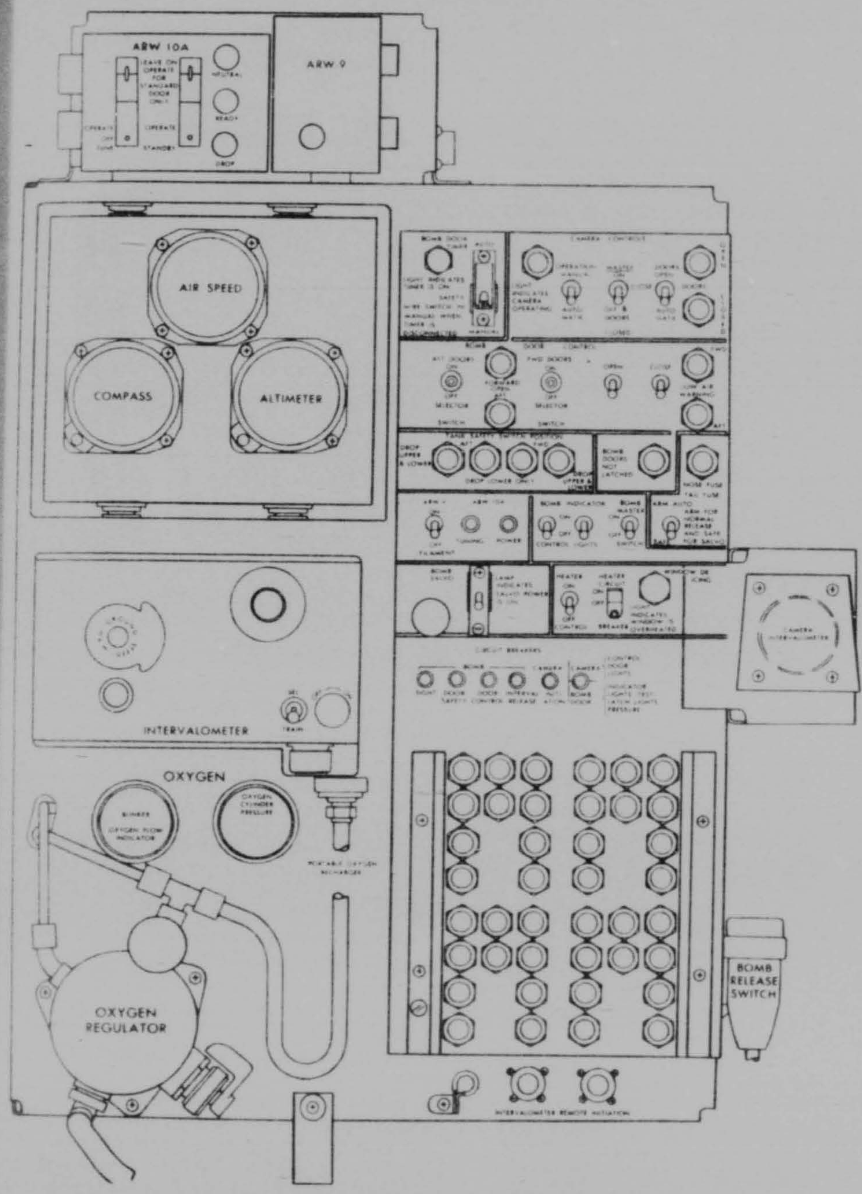


Figure 4–8. Bombardier's Control Panel.

Rack-selector Switches

Rack-selector (group selector) switches operated by controlling the "feeler current" into the rack-selector relays. These switches are located on the bombardier's control panel and give control over which bomb groups or trains will be released. One of these switches in the "off" position prevents releasing any bombs from that particular bomb train since the feeler current is prevented from closing the relays in the rack-selector relay for that release circuit.

Bomb-door Safety Switches

Bomb-door safety switches, like rack-selector switches, control the feeler current into the rack-selector relays. These switches are opened and closed by the movement of the bomb-bay doors. As the doors come fully open these switches close, thereby letting the feeler current close the relays to the bomb-release circuits. With bomb doors closed these safety switches shut off the feeler current and thus prevent closing of the relays to the bomb trains. Since the purpose of these safety switches is to prevent release of internal or bomb-bay bombs while the bomb doors are closed, it is logical that they are unnecessary on release circuits going to wing and other external racks.

Salvo Safety Switches

Salvo safety switches are operated in the same manner as bomb door safety switches. However, these prevent current reaching and energizing the salvo time-delay relays on the bomb-bay release circuits, thus preventing salvo releases of internal bombs until the bomb doors are fully opened.

Fuel-tank Safety Switches

Fuel-tank safety switches generally are located on the salvo time-delay relay unit in the bomb bay in the near vicinity of the bomb racks. These function to open and close the release circuits between the rack-selector relays and the first station in each bomb train. If one of these switches is opened ("off" position) no release impulse can be sent to that particular bomb train. The principal purpose

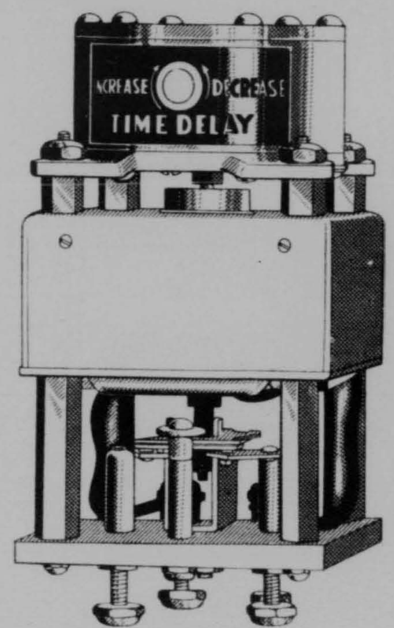


Figure 4–9. Agastat NC-28A.

of fuel-tank safety switches is to prevent accidental release of bomb-bay fuel tanks which are sometimes suspended from bomb racks by means of bomb shackles. However, they serve also as a safety measure in bomb loading, since these switches in the "off" position prevent any dropping of bombs while ground personnel are engaged in bomb hoisting.

Bomb-formation Light System

The bomb-formation light system is used on most bombing planes, and serves to warn trailing aircraft in the same formation or group that (1) the particular airplane's bomb doors are open and (2) when bombs are actually being released from that airplane. This serves not only to reduce chances of the trailing aircraft crowding the bomber during the bombing operation, but also serves as a guide to bombardiers in trailing aircraft who often depend on the lead bombardier (in the airplane leading the group) for determining the

time of bomb release.

A time-delay relay called an AGASTAT relay (Figure 4-9) controls the signaling from this system. The time-delay relay controls the white-to-red color change of the bomb-formation light below the rudder and to the rear of the fin. The light is connected in parallel with the bomb-door signal light and is illuminated when the bomb doors are fully open. A red filter controlled by the time-delay relay changes the light from white to red. The light switch on the bombardier's control panel has "bright", "dim" and "off" positions. The resistor which dims the light is in the bombardier's fuse panel. The time-delay relay is a quick-closing, delayed-opening type of relay, and is operated by impulses received from the bomb interval release, regardless of whether the bombs are being dropped in train or selective. Each impulse energizes the relay coil, causing the core to make an instantaneous and complete stroke downward, compressing a spring and causing the snap action switch to close the circuit. This energizes the bomb-formation-light solenoid which thrusts the red cylindrical filter in place around the light, where it remains as long as the solenoid is energized. When the pulse from the interval release ceases, de-energizing the coil in the time-delay relay, compression force from the spring is transmitted through the spindle to a diaphragm in the timing head. The diaphragm contains a flapper valve which allows air to be drawn in readily on the downward stroke; but on the upward stroke the air must escape through an orifice adjusted by the timing knob on the side of the relay. The orifice has been set to provide five seconds delay at sea level. When the diaphragm moves upward to a certain point, a lever trips the flapper valve, allowing the remainder of the air to escape instantly. The contacts snap to their original position, de-energizing the bomb-formation-light solenoid and allowing a spring to return the red filter to its original position. If the delay is energized again before the five seconds elapse, the core immediately travels downward, starting a complete new five-second delay. This keeps the light red while bombs are being dropped in train and allows it to become white five seconds after the last bomb has been released.

Miscellaneous Indicator Lights

Bomb-station Indicator Lights. These are used to indicate to the bombardier which bomb stations are cocked (and therefore loaded, since a release unit is not left cocked unless it is to be loaded). These indicator lights complete circuit to ground through the No. 5 pin or connection of the respective bomb rack release units. Since the No. 5 pins connect to ground only when the release units are cocked, the indicator light for a station can light on the "on" position of the "station check" switch only if that release unit is cocked. A "test" position is provided on the indicator-light switch for testing the light bulbs themselves. Thus, if a particular station light does not glow on "station check" an uncocked bomb station is indicated.

Bomb-door Indicator Lights

These are used to notify the bombardier (and, in the case of light bombers, the pilot also) when the bomb-bay doors are open. The current to these lights is controlled by switches operated by the bomb-bay doors, as are the bomb-door safety switches. When the bomb doors open fully the switch or switches close the circuit from electrical power to these indicator lights. As the doors close, these lights go out, since the switches open the circuit to power.

Bomb-release Indicator Light

This is usually located on the bombardier's control panel although the pilot's compartment may also have one. This light is connected to the B or output circuit of the bomb release interval control so that the light blinks or flashes with every bomb release interval impulse, thus serving as a check on the operation of the release circuit.

4. BOMB BAY DOOR OPERATION

General

Bomb door operation may be by means of:

Hydraulic pressure
Electrical power
Compressed air (pneumatic)
Mechanical linkage

Pneumatic System

While all four forms are used, the newest and best system appears to be the compressed air or pneumatic system. To a large extent, the mechanical operation of bomb doors seems to prevail for emergency-door operation failure of the normal door system. The pneumatic bomb-door system as used on the B-29 Superfortress will be discussed here. (The B-29 uses two bomb bays and two sets of bomb-bay doors.) The two sets of bomb doors each have their own pneumatic actuating system interconnected only by controls and pressure line. The forward bomb-bay installation consists of controls, a compressor, accumulator, air-pressure regulator valve, distribution valve, door actuators, and emergency opening springs. The rear installation is almost identical to the forward installation but does not include the springs which are used to open the forward doors in an emergency. The interconnecting pressure line allows one compressor to charge both systems in case one of the compressors is inoperative. To make this possible, the shut-off valve in the forward bomb bay must be open.

The system has both electrical and manual controls. Electrical controls are at both the bombardier's and pilot's station. They consist of two momentary switches, at each location, one for closing and one for opening the doors. The bombardier also has a selector switch which allows him to open the rear doors only. Salvo switches at the bombardier's, pilot's and right-hand gunner's stations also operate the bomb doors electrically when the bombs are salvoed. Manual control is provided for emergency operation of the bomb doors and consists of two release handles and two closing handles. The closing handles are not on all airplanes. One of the release handles is on the pilot's control stand and the other is on the left side of the forward bomb-bay cross walk. Both of the closing handles are in the bomb bays. One is located on the right side of the forward bomb bay cross walk and its operation closes the forward doors. The other is on the right-hand catwalk in the forward section of the rear bomb bay, and its operation closes the rear doors. Before the emergency-control handles in the bomb bays can be operated their protecting covers must be removed. It is necessary to close the forward doors first when using the closing handle.

During ground operation the bomb doors are normally operated by the "open" and "close" switches at the bombardier's or pilot's station. When the switch is held in the "open" position, a time-delay relay allows the solenoid-operated distribution valve to admit a small amount of air to the lower end of the bomb-door actuators. This pressure forces the actuator piston down against its cushioning air and opens the doors. To close the bomb doors, the "close" switch is held in place.

If the pneumatic system fails and no air pressure is available, either the pilot's emergency release handle or the release handle on the forward bomb-bay cross walk can be pulled to open the doors. The emergency release opens the latches on the forward bomb doors and the emergency springs force the doors open. Then air wedges on the aft ends of the doors, forcing them to the full open position. When the forward doors are approximately 70 degrees open, a cable which is attached to the left-hand forward door mechanically releases the aft-door latches, so that the built-up positive air pressure in the rear bomb bay (due to the opening of the forward doors) forces the aft doors open. Air wedges then force them to the full open position. In case of electrical system failure, if sufficient air pressure is stored in the accumulator, pulling of the release handles will allow air pressure to open the doors.

Micro switches on the door hinges turn on warning lights at the bombardier's station when the doors are open. Also warning lights are illuminated at the bombardier's and pilot's station when the latches are open.

During a bomb run, normal opening of the bomb doors is controlled by the bombsight. When the bomb door "open" switch at the pilot's or bombardier's station is actuated, the bombsight time-delay relay is not involved. The same thing occurs when the bombardier's or pilot's salvo switch is closed, except that no selection of doors is provided. The crew's salvo switch bypasses the relays entirely and allows the current to go directly to the distribution valve opening solenoids. The closing

switches bypass the relays also and allow the current to go directly to the closing solenoids.

5. UNIFIED BOMB RELEASE SYSTEM
(Figure 4-10)

Normal Release

On normal release of bombs the release impulse enters the bomb release interval control unit at terminal A. This results in an impulse going out from this unit through terminal B, blinking the bomb-release indicator light, energizing the time-delay relay (AGASTAT) of the bomb formation light system, and going on into terminal D of the rack selector relay. An impulse then comes out of E or F (depending on which of these two release circuits is set to "fire" next) of the rack-selector relay and passes through the normal-position contact points of the salvo time-delay relay, and from there through the fuel-tank safety switch and into the No. 2 pin or contact of the first cocked bomb-rack release unit in that particular bomb train. Since No. 2 pin on a cocked bomb-rack release unit connects with that unit's release solenoid, the release trips. If all rack-selector switches are closed or "on", successive release impulses would leave the rack selector relays alternately out, terminal E, then F, etc., and if two rack-selector relays are present, the release order would be E of the first rack-selector relay, then F of this same relay followed by E of the second rack selector relay, and then F of this last relay.

Salvo Release

On emergency or salvo release, closing any one of the three salvo switches would result in the following sequence of events:

Salvo warning lights would glow.

Door-opening solenoids would start the bomb doors opening.

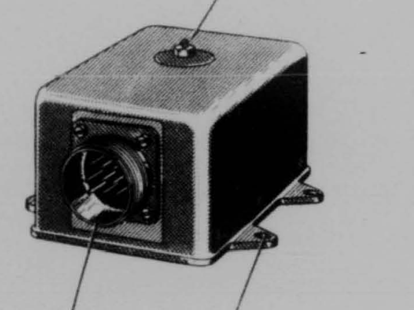


Figure 4—10. Unified Bomb Release System—Type A-5 Release Units.

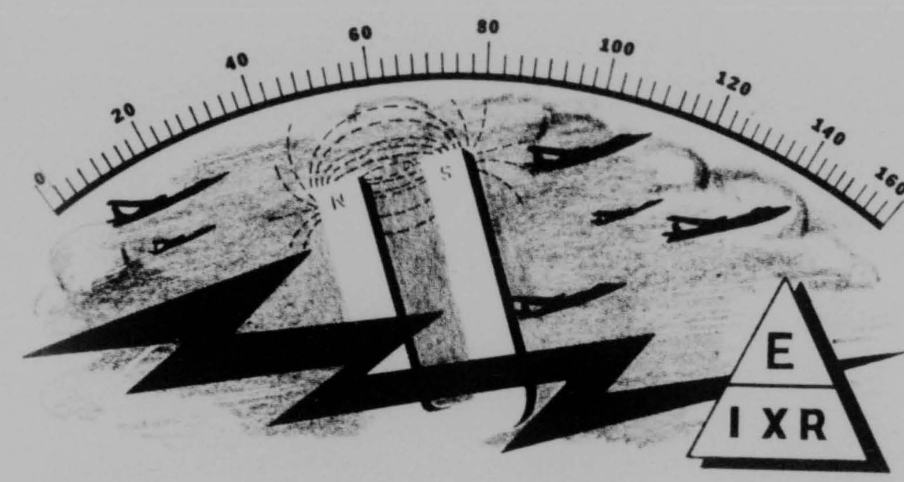
Bomb-salvo relay would close.

After the bomb-salvo relay is closed **electrical power would immediately go through the No. 1 pins of the release units,** energizing the salvo-locking solenoids in the releases.

When the bomb-bay doors have reached "full open" position, **current would flow through the coils of the salvo time-delay relays,** snapping these relays closed to the "salvo" position. This would allow the current from the closed bomb-salvo relay to flow through the fuel-tank safety switches and into the release solenoids of the release units.

The release units would then trip, with only the release levers tripping (since the salvo-locking solenoids are already energized), **thus dropping the bombs "safe".** However, had the bomb-arming control switch been "on" at the time of salvo release, the bombs would have been armed by these units.

CHAPTER 5—AC THEORY AND ELECTRONICS



SECTION I—ALTERNATING CURRENT

1. ELECTRICITY

Electricity is a fundamental quantity in nature, consisting of electrons and protons at rest or in motion. Electricity at rest has an electric field that possesses potential energy and can exert force, as in electrically charged pith balls. Electricity in motion has both electric and magnetic fields which possess potential energy and can exert force, as in an electric motor. Electricity in motion ordinarily consists of a movement of electrons through a conductor or through space.

Electricity may be generated by contact of dissimilar materials, thermo-electric action, chemical action, friction, or by electro-magnetic induction.

A conductor of electricity is a substance containing an abundance of free electrons through which electrons (current) flow freely.

An insulator or nonconductor of electricity is a substance containing relatively few free electrons, through which electron (current) flow is very limited.

It is necessary that we have conductors and insulators so that electricity may be guided or channeled where it can perform useful work.

2. ALTERNATING CURRENT

Alternating current is an electric current that is continually varying in value and reversing its direction of flow at regular intervals. Each repetition, from zero to a maximum in one direction and then to a maximum in the other direction and back to zero, is called a cycle. (Figure 5-1A.)

Direct Current

Direct current is an unidirectional current

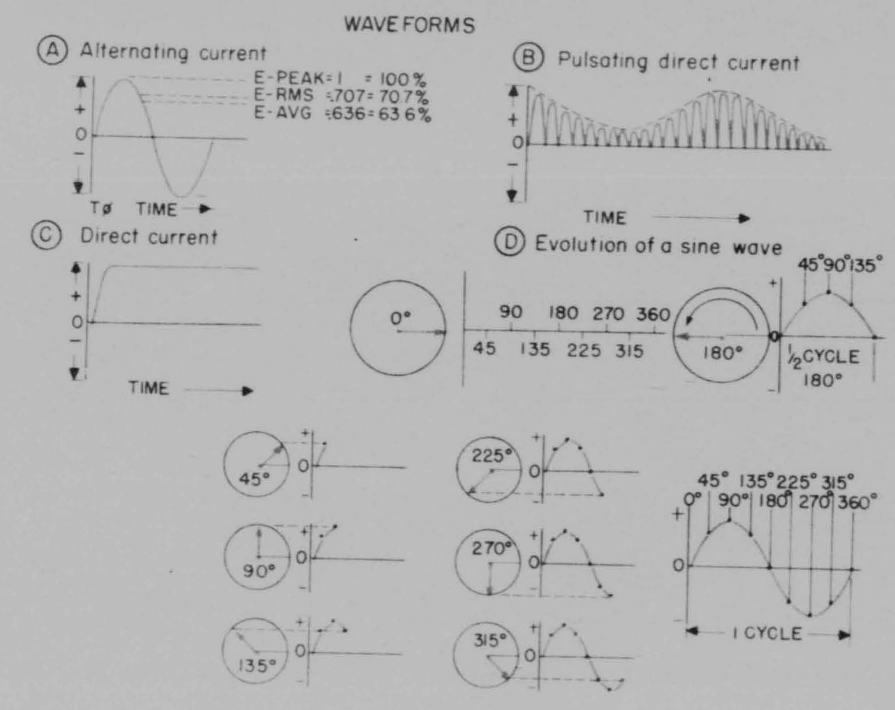


Figure 5—1. Waveforms.

(flowing in one direction at all times) in which the value is essentially constant. It is also called a continuous current. (Figure 5-1C.)

Pulsating Direct Current

A pulsating direct current is a current that is changing in value at regular intervals or irregular intervals but has the same direction at all times. Pulsating direct current is encountered in telephone use and in radio microphone circuits. Pulsating direct current may be produced by a carbon microphone whose resistance varies the direct current by the sound waves that impinge upon the carbon crystals, converting the voice or sound into pulsating direct current. (Figure 5-1B.)

3. ALTERNATORS

An alternator is an electric generator which generates an alternating current when its rotor or stator is rotated by a motor, an engine, or other prime mover. An alternating current may also be produced in a vacuum tube oscillator circuit. A simple AC generator may be constructed of a permanent magnet with a north and south pole (or with an electro-magnet that is excited by a direct current so as to set up a north and south pole), a single turn of wire placed between the north and south poles of the magnet on a shaft which may be rotated, two slip rings which are insulated from ground and from each other connected to the ends c' this single turn coil, and two sliding contact brushes to take

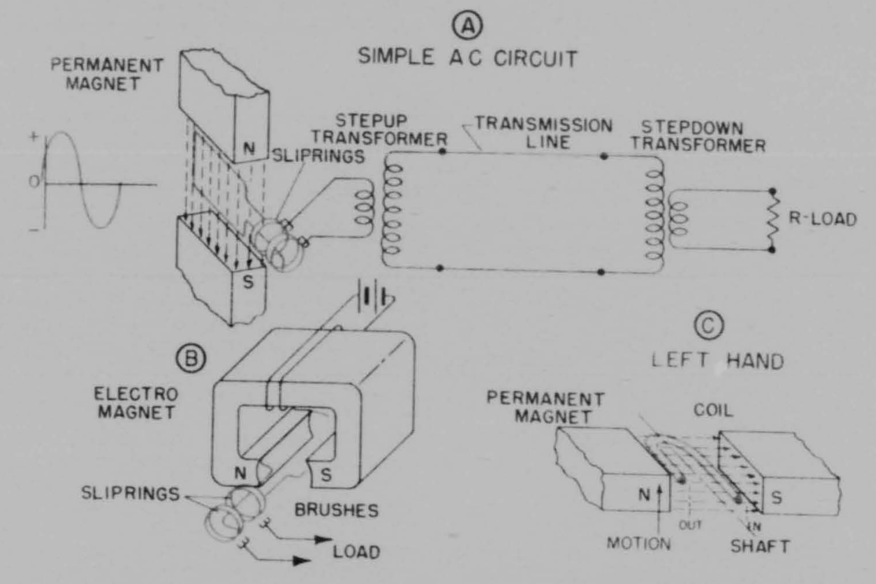


Figure 5—2. Simple Alternator, Step-up Transformer, Transmission Line, Step-down Transformer and Load.

the alternating current from the slip rings to the transmission lines and load circuit. (Figure 5-2A.)

Consider the simple generator in Figure 5-2A being turned by a prime mover in a clockwise position. If the first finger, thumb, and forefinger of the left hand are held at right angles to each other, and the first finger is pointed in a direction of the magnetic lines of force from the north to the south pole and the thumb is pointed in the direction of rotation of the single turn coil, the forefinger will point in the direction of the instantaneous current flow.

Current flow in a generator or motor is considered to flow from positive to negative. Electron flow in a vacuum tube is considered to flow from the more negative cathode to the more positive plate. It will be noted that these two theorems are in direct opposition and it will be necessary to bear this in mind when considering the current flow in motors and generators and electron flow in vacuum tube circuits.

4. DEFINITION OF TERMS OF ELECTRIC AND MAGNETIC QUANTITIES IN A SIMPLE ALTERNATING-CURRENT CIRCUIT CONSISTING OF A SIMPLE-ALTERNATOR SOURCE, A TRANSMISSION LINE, AND A LOAD (Figure 5-2A)

The alternator is an electro-mechanical device which converts mechanical energy into electrical energy; the transformer is an electrical device which steps up the voltage so that we may transfer it efficiently over long distances by a transmission line; the transmission line is the circuit which carries the electricity to the load. The load is the equipment or device which is placed or connected in the electrical circuit to absorb the power and convert it into the desired and useful form of work.

5. VOLTAGE

Voltage is the term most often used to mean electro-motive force, potential, potential difference, or voltage drop and to designate the electric pressure existing between two points which is capable of producing a flow of current when a load circuit is connected between the two points.

The instantaneous voltage produced in an alternating current generator is equal to the sine of the angle at which the conductor is passing through the lines of flux, hence the waveform of the voltage so produced follows a sine wave. When the conductor is passing through the lines of force at right angles, the voltage is maximum. If the peak value of the sine wave voltage is considered to be one or 100 per cent, the root mean square or the effective value of this voltage is considered to be .707 or 70.7 per cent of this value. The average value is considered to be .636 or 63.6 per cent of the peak value. A "RMS" volt or root mean square volt is the effective voltage. (Figure 5-1A.)

6. ELECTRIC CURRENT

An electric current is the rate of transfer of electricity. The practical unit of current is the ampere, which is a transfer of one coulomb per second.

7. CYCLE

A cycle is one complete sequence of variations in an alternating current, including a rise to maximum in one direction, a return to zero, a rise to maximum in the opposite direction, and a return to zero.

8. FREQUENCY

The frequency is the number of the cycles occurring in one second. Frequencies most commonly encountered in electric power are in the order of 25 cycles per second to 2400 cycles per second.

Audio-frequencies are those frequencies which the human ear can hear or respond to and are in the order of 20 cycles per second to 20,000 cycles per second.

The radio frequency spectrum extends from approximately 15,000 cycles per second to over 300,000,000,000 cycles per second. The radio frequency spectrum is further subdivided as follows: in very low frequencies abbreviated (VLF) 10,000 cycles per second to 30,000 cycles per second; low frequencies, abbreviated (LF) 30,000 cycles per second to 300,000 cycles per second; medium frequencies, abbreviated (MF) 300,000 cycles per second to 3,000,000 cycles per second; high frequencies, abbreviated (HF) 3,000,000 cycles per second to 30,000,000 cycles per second; very high frequencies abbreviated (VHF) 30,000,000 cycles per second to 300,000,000 cycles per second; ultra high frequency abbreviated (UHF) 300,000,000 cycles per second to 3,000,000,000 cycles per second; super high frequencies, abbreviated (SHF) 3,000,000,000 cycles per second to 30,000,000,000 cycles per second. Above approximately 100 megacycles per second or 100,000,000 cycles per second is known as the quasi optical region and radio waves at these frequencies behave in a manner similar to light waves.

The angular velocity of these sine waves frequencies is 2 pi radians per cycle. There are 57.3 degrees per radian.

9. PHASE

Phase is a quantity that specifies a particular stage of progress in any recurring operation such as a vibration or an alternating current. Phase is often expressed as an angle or part of a cycle in which case the complete cycle of operation is equal to 360 degrees (one complete rotation). When two alternating quantities pass through corresponding zero values at the same time they are said to be in phase.

The phase angle is the phase difference between corresponding stages of progress of two cyclic operations (such as between the applied voltage and the current in an inductive alternating current circuit). Expressed as an angle the terms "lag" and "lead" are used to specify which of the two quantities is first in time. The angle is expressed in degrees (one cycle equals 360 degrees or in radians, one cycle equals 6.28 or 2 pi radians).

If the voltage and current pass through their maximum and zero quantities at the

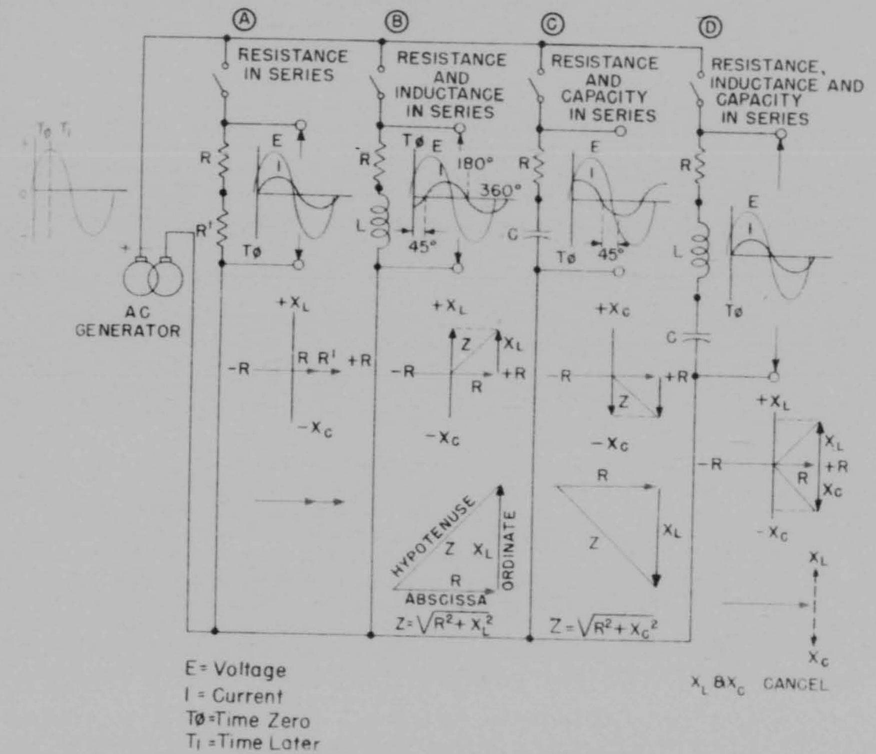


Figure 5–3. Series AC Circuits Containing Resistance, Inductance and Capacity.

same time they are said to be in phase. If the voltage and current pass through their maximum and zero at different times they are said to be out of phase. If the current leads the voltage by 90 degrees as in a capacitive circuit or if the current lags the voltage by 90 degrees, as in an inductive circuit, the circuit is said to be "reactive" and no work is done. If the voltage and current waves occur in time phase, work is performed in the load circuit, i.e., lighting a lamp, or turning a motor. The power factor of an AC circuit is equal to the cosine of the angle of the lead or lag of the current from the voltage in degrees. If the voltage and current are in phase the power factor is said to be "100 per cent."

10. RESISTANCES IN SERIES IN AN AC CIRCUIT

Resistances in a series AC circuit add arithmetically as in a DC circuit. Resistances in parallel in an AC circuit are equal to the reciprocal of the sum of the reciprocals of each resistance as in a DC circuit. (Figure 5-3A.)

11. INDUCTANCE

Inductance is that property of an electric circuit or two neighboring circuits which determine how much electro-motive force will be induced in one of the electro-motive cir-

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cuits by change of current in either of them. Inductance is measured in "henrys" and designated by the letter "L."

Self-inductance is that property of an electric circuit which determines, for a given rate of change in current in the circuit, the electromotive force induced in the same circuit. Self-inductance is measured in "henrys" and designated by letter "L."

Mutual-inductance is the common property of two associated electric circuits determining, for a given rate of change of current in one of the circuits, the amount of electromotive force induced in the other. Mutual inductance is measured in "henrys" and is designated by the letter "M."

Inductive reactance is that type of reactance which is due to the inductance of the circuit or coil. It is measured in ohms, designated by X_L, and is equal to the inductance in Henrys multiplied by 2 pi times the frequency in cycles.

$$X_L = 2\pi fL.$$

The mechanical analogy of an inductance is similar to the compression of a spring, in other words, the inductance tends to cause the current to be pushed behind or lag behind the voltage. (Figure 5-3B.)

12. CAPACITANCE

Capacity is the electrical size of a capacitor, determining the amount of electrical energy which can be stored in it by a given voltage at an amount of alternating current which will flow at a given frequency. The basic unit of capacitance is a "farad". It is the value which will pass a current of one ampere when the voltage across the capacitor is changing at the rate of one volt per second. The farad is too large a unit for radio and electrical work, hence, micro-farad (one millionth of a farad) and micro-micro-farad (one millionth of a micro-farad) are commonly used. Capacitance exists when two conductors are separated by an insulating material commonly known as a di-electric.

Capacity in farads in series AC circuit is equal to the reciprocal of the sum of the reciprocals.

Capacitance in an AC circuit in parallel is equal to the arithmetic sum of all of the capacitors in parallel.

Capacitive reactance is that type of reactance which is due to the capacitance of a capacitor or circuit. Capacitive reactance is measured in ohms, designated by the Letter X_c and is equal to the reciprocal of the product of 2 pi times the frequency in cycles per second and the capacitance in farads. (Figure 5-3C).

$$X_c = \frac{1}{2\pi fC}$$

The mechanical equivalent of a capacitance in an AC circuit is equivalent to the elasticity of a spring that is under tension, in other words, the capacitive reactance tends to pull the current ahead of the voltage. (Figure 5-3C.)

Capacitors or condensers are made in several types such as electrolytic, a capacitor consisting of a combination of two conductors at least one of which is a valve metal, separated by an electrolyte. A di-electric film, usually a thin layer of gas, is formed between the conductors, adjacent to the surface of one or both. A mica capacitor is a fixed capacitor employing mica sheets as the di-electric material between adjacent plates. The complete unit is encased in molded bakelite. A variable capacitor is an air di-electric capacitor whose capacitance can be varied by adjusting the amount of meshing between a fixed set of plates (the stator) and a rotating set of plates (the rotor), or sometimes by varying the spacing between fixed plates as in a trimmer capacitor. Other types of variable air di-electric capacitors are straight-line capacity condensers in which the rate of change in capacity is linear as the rotor is turned through 180 degrees. A straight-line frequency air di-electric variable capacitor whose rate of frequency change in a specific circuit is linear through 180 degrees of rotation of the rotor.

13. OHM'S LAW FOR AC

Ohm's law for AC states that the current in an AC circuit is directly proportional to the total electro-motive force in the circuit and inversely proportional to the total impedance,

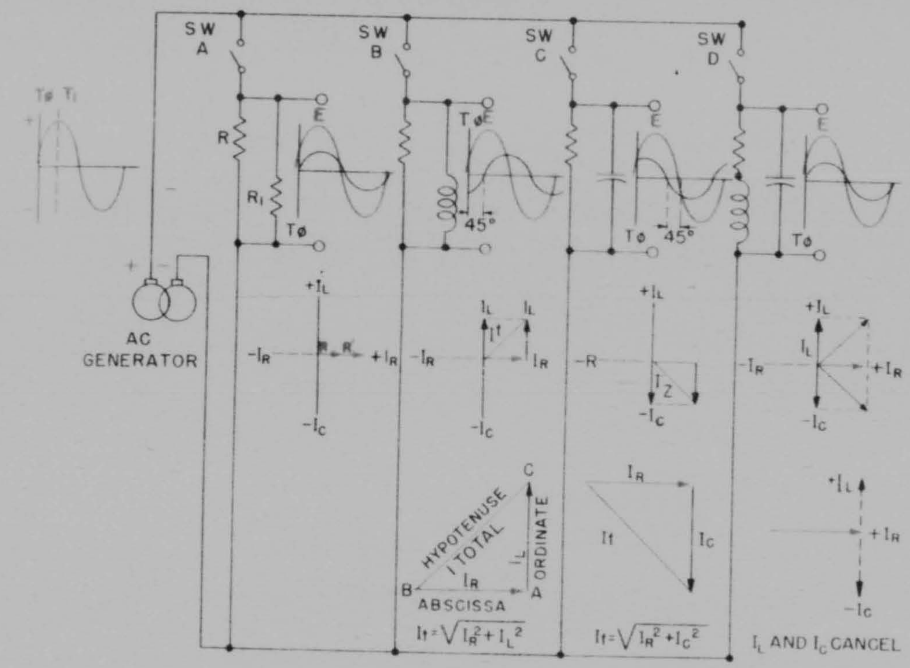

Figure 5—4. Parallel AC Circuits Containing Resistance, Inductance and Capacity.

which is the vector sum of the resistance and the reactance in the circuit. (Figure 5-3.)

14. WATTS' LAW FOR AC

Watts' law for AC states that the true power in watts is equal to the effective volts multiplied by the effective amperes and then multiplied by the circuit power factor. The apparent power in watts is equal to the effective volts times the effective amperes in an alternating current circuit. The apparent power includes the true power and the wattless or reactive components. The wattless component of the apparent power in an alternating circuit current is delivered to the circuit during part of a cycle, but is returned to the source during another part of the cycle. The true power in an AC circuit is usually called a "kilowatt," abbreviated KW (1,000 watts). The apparent power in an alternating circuit current is usually called "kilovolt amperes" abbreviated KVA (1,000 volt amperes).

15. SERIES AC CIRCUITS

Series AC circuits contain resistances in series. (Figure 5-3.) If switch A were closed, connecting resistances "R" and "R'" in series to the AC generator, the voltage would cause a current to flow. The voltage and current would be in phase and would pass through the zero and maximum magnitudes at the same times. If switch "B" were closed connecting resistance "R" and inductance "L" in series, the inductance would cause the current to lag the voltage. If the resistance in ohms and the inductive reactance in ohms were equal the lag would be approximately 45 degrees. The impedance "Z" in ohms would be the vector sum of the resistance and the inductive reactance.

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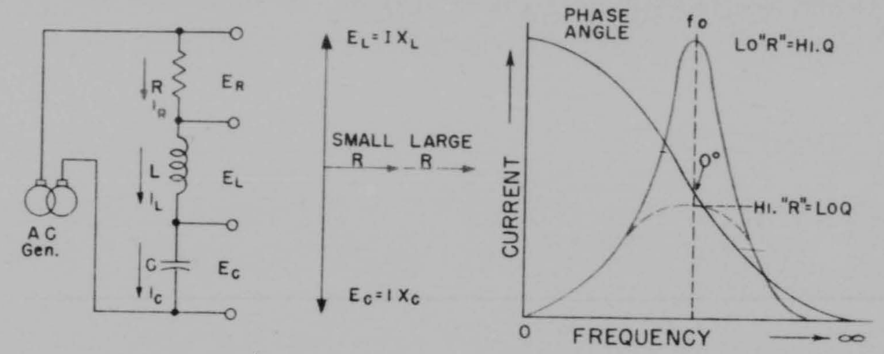


Resonant Freq. $= f_0 = \frac{1}{2\pi\sqrt{LC}}$

$2\pi = 6.28$

L = Inductance Henries

C = Capacity Farads

$2\pi f = \omega$ (Omega)

$Q = \omega L/R$

Resonance

$\omega L = \frac{1}{\omega C}$

Phase Angle = 0° Degrees

Z = R

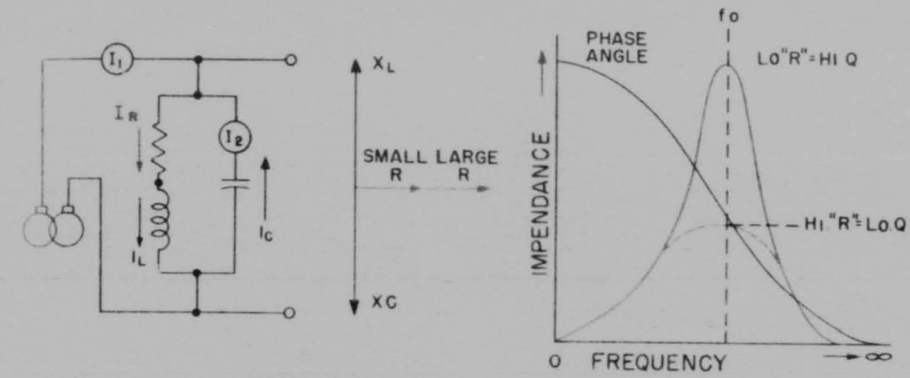
Figure 5–5. Series Resonance.

If switch "C" were closed connecting resistance "R" and capacitance "C" in series in this AC circuit the condenser would cause the current to lead the voltage. If the resistance in ohms were equal to the capacity reactance in ohms the current would lead the voltage by approximately 45 degrees. The impedance Z in ohms would be the vector sum of the resistance and capacitive reactance.

If switch "D" were closed connecting the resistance "R", the inductance "L" and the capacitor "C" in series with the generator, and if the inductive reactance in ohms were equal to the capacitive reactance in ohms, the two reactances would be canceled out and the total impedance offered to the flow of an AC current through this series circuit would be the resistance "R". The voltage and the current would be in time phase with each other and would pass through their zero points and maximum magnitudes instantaneously.

16. PARALLEL AC CIRCUITS (Figure 5-4)

If switch "A" were closed connecting resistance "R" and "R" in parallel in the AC circuit the voltage produced by the generator would cause a current to flow. The voltage and the current would be in phase and would pass through their zero points and maximum magnitudes at the same time. If switch "B" were closed connecting resistance "R" and inductance "L" in parallel in this AC circuit, the voltage would cause a current to flow, but the inductive reactance of "L" would cause the current to lag the voltage. The total current flowing in this parallel circuit would be equal to the vector sum of the current through the resistance and the current through the inductance. If switch "C" were closed, the voltage would cause a current to flow but the capacitive reactance would cause the current to lead the voltage. The total current flow would be the vector sum of the current through the resistance and the current through the capacitor. If switch "D" were closed connecting the resistance "R" and inductance "L" and parallel with the capacitor "C" the voltage would cause a current to flow; if the inductive reactance in ohms of "L" is equal to the capacitive reactance in ohms of capacitor "C" the two would cancel



Resonant Freq. $= f_0 = \frac{1}{2\pi\sqrt{LC}}$

$\pi = 6.28$

L = Inductance Henries

C = Capacity Farads

$2\pi F = \omega$ (Omega)

$Q = \omega L/R$

Resonance

$\omega L = \frac{1}{\omega C}$

Phase Angle = Zero Degrees

$Z = \frac{(2\pi FL)^2}{R} = 2\pi FLQ$

Figure 5–6. Parallel Resonance.

each other and the total current flow in this parallel circuit would be small and the impedance would be large due to the condition of resonance. The voltage and current would be in time phase with each other.

17. SERIES RESONANCE (Figure 5-5)

A series resonant circuit is a circuit with an inductance and capacitor in series, having electrical values such that the inductive reactance of the inductor is equal to the capacitive reactance of the capacitor at the frequency being impressed upon the circuit. At this condition, corresponding to resonance, the current is maximum and the voltage across either the inductor or the capacitor may be several times the voltage applied to the combination, depending on the "Q" of the circuit. The only impedance offered to the flow of current across this series resonant circuit is the resistor as the inductive reactance and the capacitive reactance cancel each other out. At low frequencies the capacitive reactance of the circuit is large and the inductive reactance is small so that much of the voltage drop is across the condenser, while the current is small and leads the applied voltage by nearly 90 degrees. At high frequencies the inductive reactance is large and the capacitive reactance is low, resulting in a small current which lags nearly 90 degrees behind the applied voltage, and most of the voltage drop is across the inductance. In between these two extremes, there is a frequency called the resonant frequency at which the capacitive and inductance reactances are exactly equal and consequently neutralize each other, leaving only the resistance of the circuit to oppose the flow of current. The current at the resonant frequency is accordingly equal to the applied voltage divided by the circuit resistance, and is very large if the resistance is low. The characteristics of the resonant circuit depend primarily upon the ratio of inductive reactance to the circuit resistance, that is, upon inductive reactance divided by resistance. This ratio is frequently denoted by the symbol "Q" and is called the circuit "Q". In the usual resonant circuit the radio frequency re-

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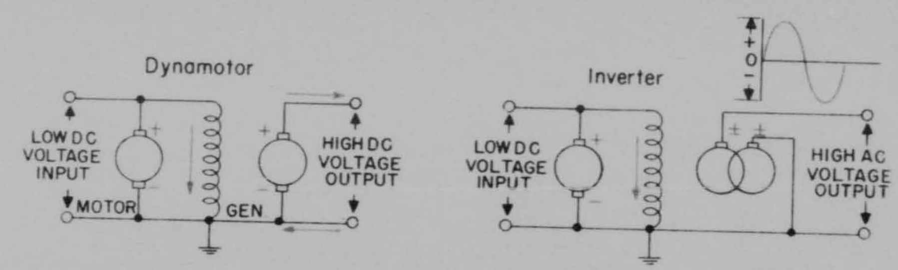

Figure 5–7. Dynamotors and Inverters.

sistance circuit is made up almost solely of coil resistance because the losses in a properly constructed condenser are negligible in comparison with those of the coil. The phase angle of the impedance at resonance is zero.

$$\text{Resonant Freq.} = F_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$\text{At Resonance } \omega L = \frac{1}{\omega C}$$

18. PARALLEL RESONANCE (Figure 5-6)

Parallel resonance is a steady state condition that exists in a circuit comprising an inductance and capacitance connected in parallel, when the inductive and capacitance reactance values are equal the current entering the circuit from the supply line is then in phase with the voltage across the circuit. A parallel resonant circuit at resonance (when the inductive reactance equals the capacitance reactance) the circuit has a high impedance and a high signal voltage value is developed across it at frequency to which the circuit is resonant. At high frequency the inductance has a high reactance compared with the capacity, resulting in a large leading line current and a correspondingly low circuit impedance that is leading in phase. At very low frequencies the inductive branch draws a lagging current while the leading current of the capacitive branch is small, resulting in a large lagging line current and a low lagging circuit impedance. In between these two extremes there is a frequency at which the lagging current taken by the inductive branch and the leading current entering the capacitance branch are equal and being 180 degrees out of phase are neutralized, leaving only a small resultant current flowing in the line. The impedance of the parallel circuit will then be, in effect, a very high resistance to this particular frequency.

19. TRANSMISSION LINES

A transmission line is the conductor used to transfer signal or power energy from one location to another. Most alternating current power transmission systems consist of the following elements: generating stations, step-up transformer stations, transmission lines suitably insulated to transmit this high voltage, step-down transformers and secondary line and load networks. Radio frequency transmission lines are usually spaced, paired lines, coaxial lines, or wave guides. A coaxial line is a metal tube having at its center a wire supported by insulators, it is also called a "concentric" line. A wave guide is a hollow tube or di-electric cylinder capable of propagating electro-magnetic waves through their interiors or radiating them into space, at frequencies of about 1,000 megacycles and higher. Widths or diameters range from ½ inch to 12 inches or more. There are two classes of guides, di-electric guides consisting of solid di-electric cylinders surrounded by air and having little practical use due to the high losses occurring in solid di-electrics, conducting guides which are air filled, gas filled, or evacuated hollow metal tubes which are circular, rectangular, or other cross section. The metal wall is called the sheath of the guide. It may be any conducting material and may be as thin as is practicable. Electro-magnetic waves travel through guides in much the same manner as sound waves travel through a speaking tube.

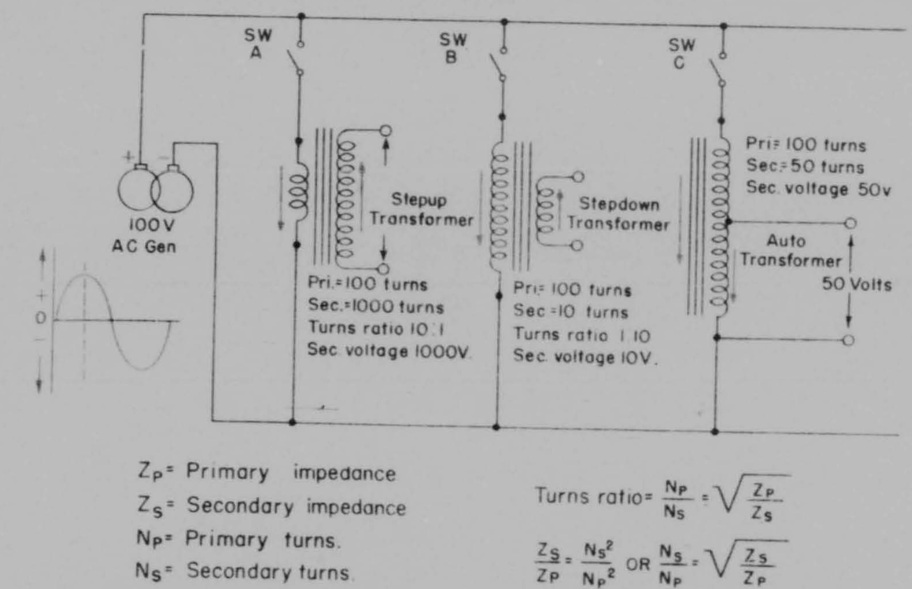

Figure 5–8. Transformers.

20. ANTENNAS

Antennas are a conductor or system of conductors for radiating or receiving radio waves.

A di-pole antenna is a simple antenna, ½ wavelength long. A wavelength in meters being equal to 300,000 frequency kilocycles.

A parabolic reflector brings parallel radio waves to a focus at a point for receiving, or produces a narrow parallel beam when a radio wave source is placed at its focus for transmitting. When a simple di-pole radiator is placed at the focus of a parabolic reflector the antenna gain over a single dipole may be 10 to 20 DB greater, or 100 to 1000 times as great.

21. INVERTERS

An inverter is a device for converting direct current into alternating current. It may be electro-mechanical, a vibrator, or electronic, as in a thyratron inverter circuit.

Inverters are commonly used in aircraft to supply 400 cycle, 110-volt power for radar equipment. See Figure 5-7.

22. DYNAMOTORS

A dynamotor is a combination electric motor and generator having two or more separate armature windings and a common set of field poles. One armature winding receives direct current as a motor and produces rotation, and the other generates current as a dynamo or generator. It is used to change a direct voltage to an alternating voltage or to a higher direct voltage, chiefly in connection with airborne radio and radar equipment.

23. TRANSFORMERS

A transformer is an electric device, without continuously moving parts, which transforms electric energy from one or more circuits to one or more circuits by means of electro-magnetic-induction without change in frequency, but usually with a change in the value

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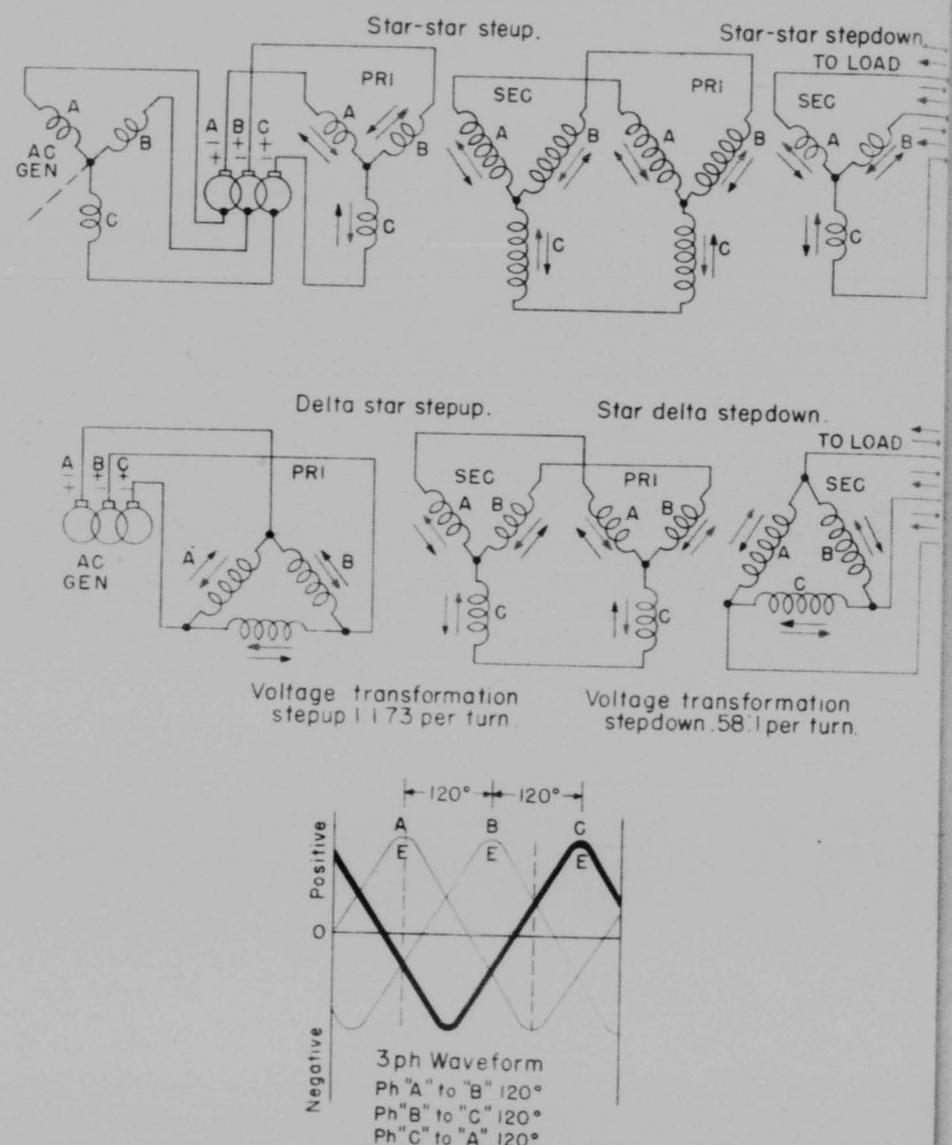


Figure 5–9. 3 Phase Transformers.

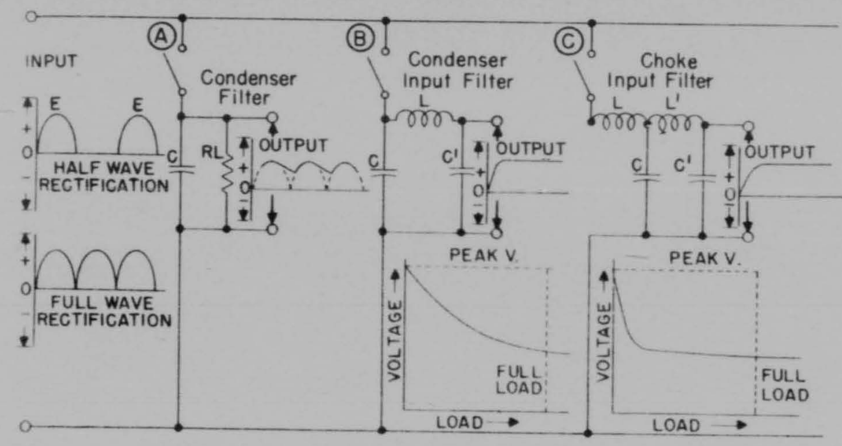


Figure 5–10. Power Filters.

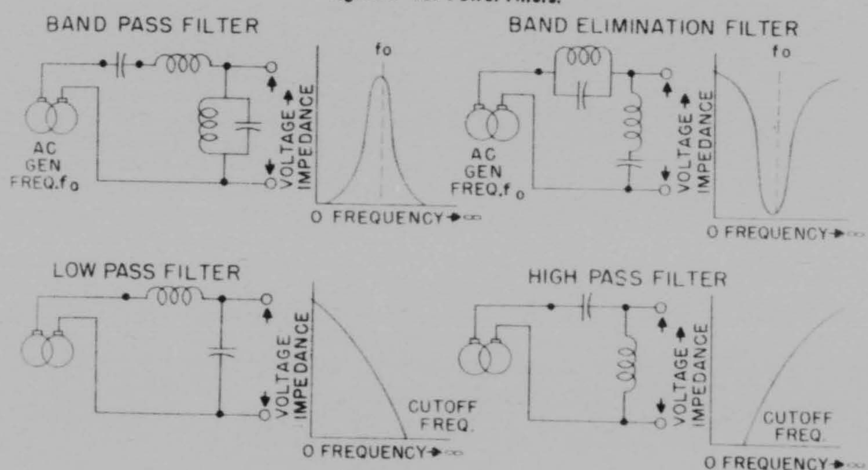


Figure 5–11. RF Filters.

of voltages.

Transformers may be single phase, two-phase, three-phase, or auto-transformers. (Figures 5-8 and 5-9.)

24. FILTERS

An electric filter is a selective circuit network designed to pass direct current or alternating current within a continuous band of frequencies, while substantially reducing the amplitudes of currents at undesired frequencies.

Filters may be of the band pass, band elimination, low pass filter, and high pass filters for radio frequencies.

Power filters are used to remove the ripple frequency after rectification. (Figures 5-10 and 5-11.)

SECTION II—VACUUM TUBES

1. INTRODUCTION

Since radio, television, radar and all other electronic circuits are built around vacuum tubes, this section will be devoted to the description and the simple operation of the principal tubes used in radar circuits.

2. THE ELECTRON AND ITS EMISSION

The whole foundation of electricity is based upon the "electron," a minute, negatively charged, particle. Atoms, of which all matter is composed, consist of a positively charged nucleus around which are grouped a number of electrons. The physical properties of any material depend upon the number of electrons and the size of the nucleus. In all matter there are a certain number of free electrons. The movement of these free electrons is known as a "current" of electricity. If the movement of electrons is in one direction only, the current is "direct." If, however, the source of voltage is alternated between positive and negative, the flow of electrons will likewise alternate; this is known as "alternating" current.

If certain metals, or metallic substances such as metallic oxides, are heated to a high temperature either by means of a flame or by passing current through them, they have the property of throwing off, or emitting, electrons. The element in a vacuum tube which is heated to emit electrons is called the "cathode."

If the cathode is heated to a high temperature in open air, it will burn up because of the presence of oxygen. For this reason the cathode is placed in a glass or metal bulb from which all air has been removed. Such a space is known as a "vacuum." Since it is difficult to heat an element in a vacuum tube by means of fire or flame, the cathode, which is in the form of a filament, is directly heated by passing a current through it.

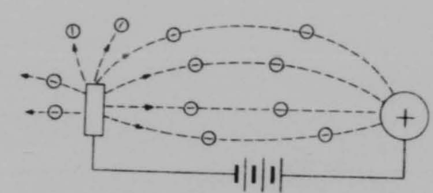


Figure 5—12. Emitted Electrons Attracted by a Positively Charged Body.

Any isolated, positively charged, body in the vicinity of the electron emitter will attract the negatively charged electrons. The positive charge on the body will soon be canceled by the electrons attracted to it unless some means is employed to remove the electrons as fast as they arrive. This can be done by connecting a source of constant voltage between the positively charged body and the electron emitter (Figure 5-12). This is the general arrangement in a two-element tube, or "diode." It is also the basis of operation of all types of vacuum tubes.

The emitter, or cathode, of a vacuum tube may resemble the familiar incandescent lamp filament which is heated by passing a current through it. The positively charged body usually surrounds the emitter and is called the "plate," or "anode." It should be noted that electrons travel from negative to positive.

Two types of cathodes, or emitters, are used in radio tubes. In one, known as the "filament" or "directly heated" type, the heating current is passed through the cathode itself. In the other, known as the "indirectly heated" type, the current is passed through a heating element, which in turn heats the cathode to a temperature sufficiently high for electron emission. In the indirectly heated type, the cathode is an oxide-coated metal sleeve which is placed over the heater element.

The higher the temperature of the cathode, the more electrons it will emit. However, if too much voltage is applied to a cathode, the

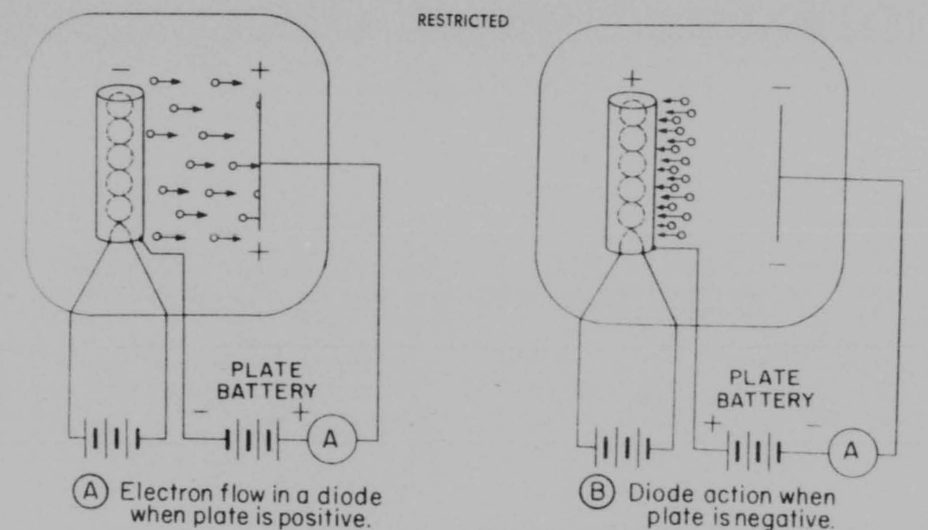


Figure 5—13. Diode Operation.

heavy current flow will cause the filament or heater to burn out. The safe filament or heater voltage is determined by the manufacturer, and this voltage rating must be observed for satisfactory operation. The cathode of a tube will not continue to emit electrons indefinitely. After several thousand hours of operation, the number of electrons emitted will gradually decrease, until finally an insufficient number is emitted for proper operation. The decrease in emission capacity is due to the chemical change which takes place in the cathode. This is one of the reasons why tubes wear out.

3. SECONDARY EMISSION

When an electron stream strikes an electrode surface, or, indeed, any surface, an emission of "secondary electrons" is produced. There is no known substance in which this effect does not occur. In fact, there is no known substance which acts as a perfect absorber of electrons that strike it.

As will be explained later, secondary radiation, in electronic tubes, is sometimes useful, and at other times, undesirable.

4. THE DIODE AND ITS OPERATION

The diode is the simplest type of vacuum tube, and consists of only two elements—a cathode and a plate.

If the positive terminal of a battery is connected to the plate of a diode and the negative terminal is connected to the cathode, the plate will be positive with respect to the cathode. Since the electrons emitted by the cathode are negative particles of electricity, and there is a positive charge on the plate, the electrons emitted by the cathode will be drawn to the plate (Figure 5-13A). In other words, there is an electron flow through the tube, which results in a current flow in the circuit. If the flow of current in the circuit is measured by meter A (Figure 5-13A), while the voltage applied to the plate (known as "battery voltage" or "plate voltage") is increased, it will be seen that the current flow through the tube, known as the "plate current," increases. This is illustrated by the plate-voltage plate-current curve of Figure 5-14.

When the negative terminal of a battery is connected to the plate of the diode and the positive terminal is connected to the cathode (Figure 5-13B), the plate will be negative with respect to the cathode; therefore, no electrons will be attracted to the plate. Since no electrons are traveling across to the plate, no current will flow through the tube.

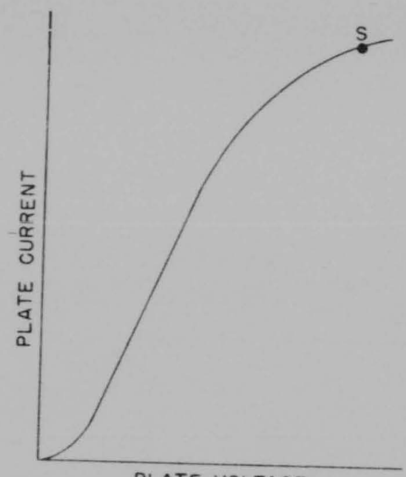


Figure 5—14. Plate Current Flow in a Diode.

The diode is a conductor when the plate voltage is positive. This property of the diode permits the use of this tube for two very useful functions—rectification and detection. Circuits to perform these two functions will be discussed in section III of this volume.

5. DIODE CHARACTERISTIC CURVES

The plate-current, plate-voltage curve shown in Figure 5-14 is an important characteristic of the diode vacuum tube, because it shows the amount of current that a diode will pass for any given plate voltage. Different types of diodes may have slightly different characteristic curves. All of these curves, however, indicate one important fact; the load, or plate current is not proportional to the applied, or plate voltage. For this reason, Ohm's law is strictly applicable only to small increments, or changes, of currents and voltages. In general, current-voltage relations in vacuum-tube circuits are studied by means of experimentally obtained characteristic curves.

The curved portions, or bends, in the graph of Figure 5-14 are the result of certain variations in the action of the diode. When the plate voltage is low, the electrons nearest the cathode are repelled back to the cathode by the accumulated emitted electrons which are a little farther from the cathode, and only those electrons which are nearest the plate are attracted to the plate. This repelling effect around the cathode is known as the "space charge." For intermediate values of the plate potential, the space charge in the vicinity of the cathode is reduced by the attraction of more electrons to the positively charged plate, and any increase in plate potential produces an appreciable increase in current, as shown by the curve of Figure 5-14. For large values of plate potential, when the space charge is completely removed, the number of electrons reaching the plate per second is limited by the number emitted per second by the cathode, and is independent of plate potential. This latter condition is referred to as "saturation," and a place along the curve (point S in Figure 5-14) is called the "saturation point."

6. DRY RECTIFIERS

The characteristic of undirectional electron flow between the two elements of a diode can be attained through the use of the so-called "barrier layer effect" as well as through the use of the two-element vacuum tube. Two common electronic components which utilize this effect are the "dry-disk rectifier" and the "rectifying crystal." Two common types of dry-disk rectifiers are the copper-oxide rectifier and the selenium rectifier. Copper-oxide rectifiers are frequently employed in power supplies where power line frequency alternating current must be converted into DC at moderate voltage (6 to 30 volts), and at currents from a few hundred milliamperes to 10 or 20 amperes. Selenium rectifiers are now also used in this field, and in some power supplies where moderate currents at from 1,000 to 5,000 volts are required.

Rectifying-crystal diodes are frequently employed in the rectification of r-f energy. The predecessor of these modern units is the galena or silicon crystal used in the "wireless" days of radio. Crystal diodes are available in two general types. The first type was developed for use as a mixer in s-h-f radar receivers and utilizes a small piece of silicon crystal sealed in a ceramic holder with a "cat whisker" factory-adjusted to the proper spot on the crystal. It is suitable for rectifying only a very small amount of energy, although types are available for use up to 30,000 megacycles. The second type, which uses a germanium crystal element, has more recently been developed for use at higher energy levels and at frequencies up to about 100,000 megacycles. It is widely used as a detector or demodulator in high-frequency FM and AM receivers. This type is also especially well suited for use as the rectifying element in field-strength meters and modulation monitors.

7. THE TRIODE AND ITS OPERATION

The triode differs in construction from the diode only in the addition of another element, called the "grid." The grid is a cylindrical structure made of a fine wire spiral or mesh, which is placed between the cathode and the plate of the tube so that all the electrons leaving the cathode must pass through it in order to reach the plate. Figure 5-15 shows the arrangement of the grid, cathode, and plate in a typical triode. The grid is placed considerably closer to the cathode than is the plate, and consequently will have a very great effect on the electrons which pass through it.

If a triode is connected in a simple circuit, as shown in Figure 5-16A, the action of the grid can be studied. When a small negative voltage (with respect to the cathode) is put on the grid, there is a resultant change in the flow of electrons within the vacuum tube. Since the electrons are negative particles of electricity, and like charges repel one another, the negative voltage on the grid will tend to repel the electrons emitted by the cathode, and thus tend to prevent them from passing through the grid on their way to the plate. However, since the plate is considerably positive with respect to the cathode, its attraction for the electrons is sufficiently strong to enable some of them to pass through the grid and reach the plate in spite of the opposition offered them by the negative voltage on the

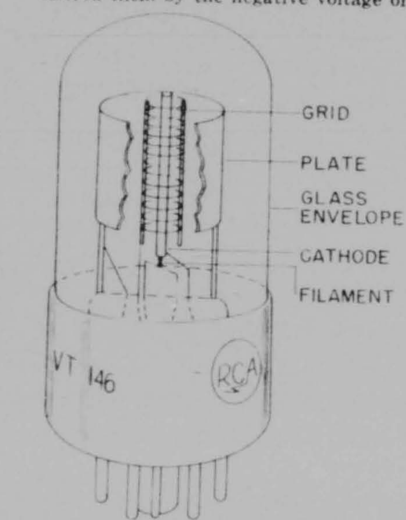


Figure 5—15. Typical Triode Construction.

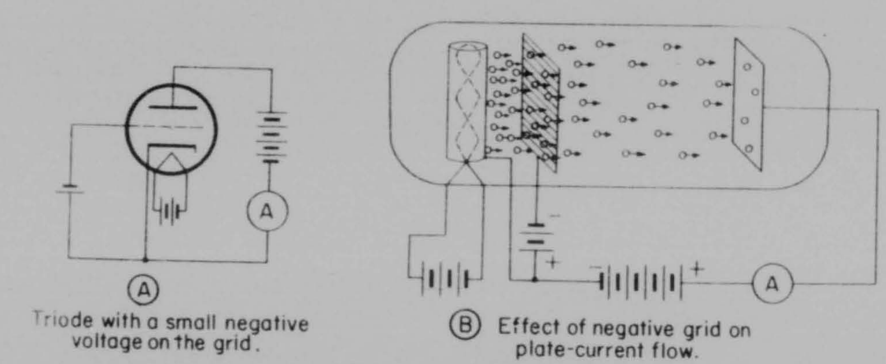


Figure 5—16. Triode Biased Negatively.

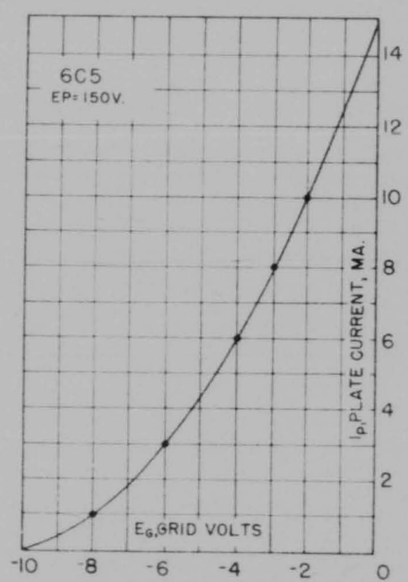


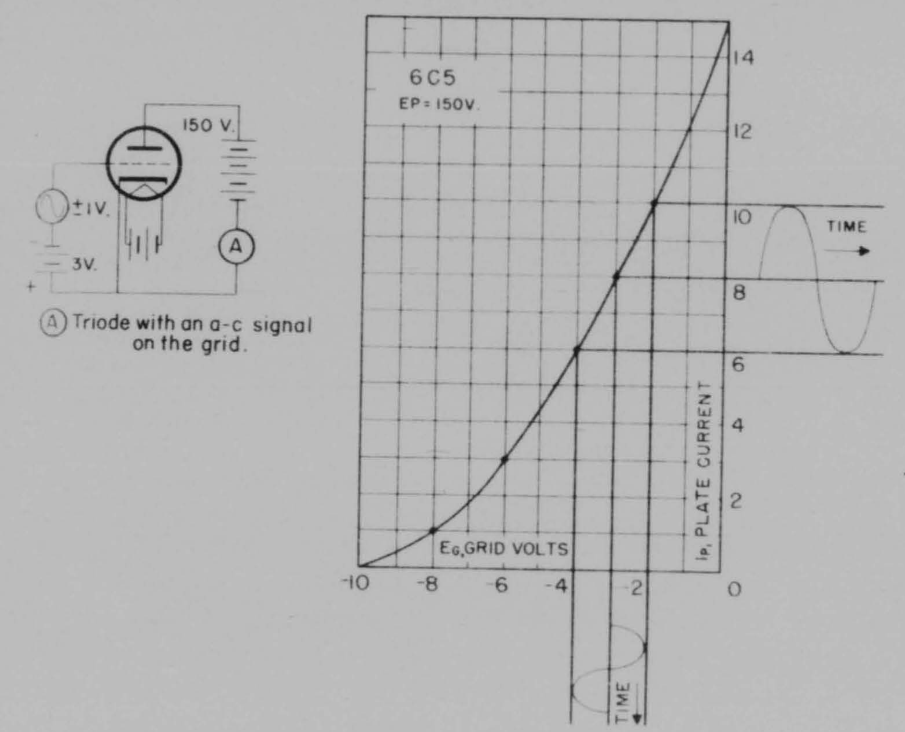
Figure 5—17. Grid-Voltage Plate-Current Curve.

grid. Thus, a small negative voltage on the grid of the tube will reduce the electron flow from the cathode to the plate (Figure 5-16B) and consequently will reduce the value of plate-current flow between the cathode and the plate of the tube.

If the plate current in the circuit of Figure 5-16A is measured by means of meter A, while holding the plate voltage constant and making the grid of the tube gradually more negative with respect to the cathode, the plate current will vary as shown in the grid-voltage plate-current curve of Figure 5-17. Such a curve is also known as an E_G—Ip characteristic curve. From this curve, it can be seen that as the grid of the tube is made more negative, less plate current will flow, since the more negative the grid the fewer electrons it permits to pass on to the plate. In the case of this particular tube (type 6C5), it will be noted from the characteristic curve that if the grid is made sufficiently negative (—10 volts), the plate current drops to zero. Thus, this value of negative grid voltage has cut off the flow of electrons within the tube. A negative voltage which is applied to the grid of a tube to hold its plate current flow at a given value is known as the "grid-bias" voltage, or more simply, the "bias"; that value of grid bias which will cut off the flow of plate current is called the "cutoff bias" for that tube. Since the plate current in a tube increases as the plate voltage is increased, the bias required to cut off plate current flow will increase as the plate voltage applied to the tube is increased.

If the triode is connected in a circuit where an AC (signal) voltage of one volt is applied to the grid in series with 3 volts of negative bias (Figure 5-18A) on the positive half-cycle of the AC signal there will be —2 volts applied to the grid with respect to the cathode (+1—3 = —2); and on the negative half-cycle there will be —4 volts on the grid of the tube (—1—3 = —4). From the grid-voltage plate current curve shown in Figure 5-18B, it can be seen that when there is no AC signal applied to the tube, the plate current will be fixed at 8 milliamperes by the 3 volts of bias supplied by the bias battery. When the AC signal is applied to the tube, on the positive half-cycles there will be —2 volts on the grid of the tube and the plate current will increase to 10 milliamperes; but on the negative half-cycles there will be —4 volts on the grid and the plate current will decrease to 6 milliamperes. Thus, a 1-volt AC signal will cause a plate current change of 4 milliamperes in this tube. This can be demonstrated graphically by showing the AC voltage wave form on the grid-voltage scale of the E_G-I_P characteristic curve, and plotting the plate-current wave form on the plate-current scale of the graph (Figure 5-18B).

An examination of Figure 5-18B will show that the wave form of the plate current variation is an exact reproduction of the wave form of the AC voltage applied to the tube. By carrying this process further, it can be shown that if the negative bias is increased to 5 volts, so that the grid voltage varies from —4 to —6 volts over the AC cycle, the plate current change will vary from 3 to 6 milliamperes, showing a total change of only 3 milliamperes. If the negative bias voltage is



B Plate current waveform resulting from an a-c grid voltage.

Figure 5—18. Operation of a Simple Triode Circuit.

increased to 9 volts, so that the grid voltage varies from —8 to —10 volts over the AC cycle, then the plate current change will be only 1 milliampere. From this it can be seen that if the negative bias is increased, there is a resultant decrease in the plate current change for a given signal input. This method of controlling the output of a tube by varying the bias voltage is often used as a means of volume control. It should be noted, however, that if the grid voltage is increased to too high a negative value (Figure 5-19A), there is noticeable distortion of the output plate current wave. Distortion also results if the cathode temperature is lowered to such a degree that the emission is insufficient (Figure 5-19B). A distorted output is generally, but not always, objectionable.

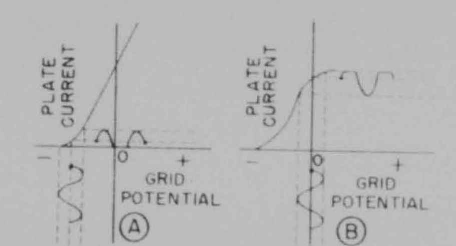
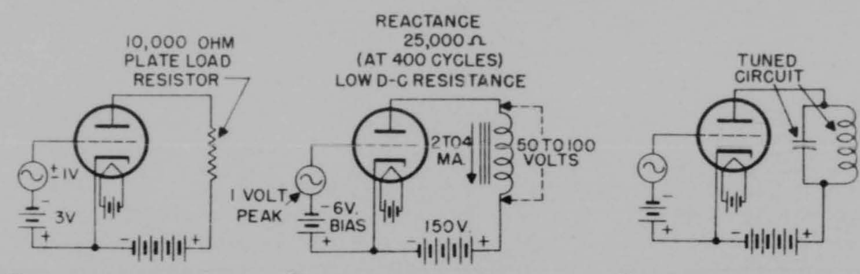


Figure 5—19. Distortion Due to a High Grid Bias and Low Cathode Temperature.



(A) Triode using a resistor as a plate load.
(B) Triode using an inductor as a plate load.
(C) Triode using a tuned circuit as a plate load.

Figure 5—20. Vacuum Tube Load Circuits.

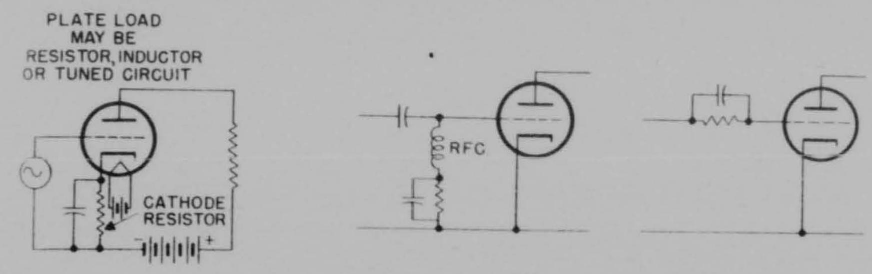
8. VACUUM TUBE PLATE LOADS

In order to make use of the variations in the plate current of a vacuum tube due to variations in grid voltage, some sort of a device must be present in the plate circuit of the tube to act as a load. This plate load can be a resistor, an inductor, or a tuned circuit.

A typical triode circuit with a resistor used as a plate load is shown in Figure 5-20A. If the tube in this circuit is biased at —3 volts and the applied AC signal voltage to the grid is 1 volt, the plate current variation of 4 milliamperes will produce a voltage variation of 40 volts across the 10,000-ohm resistor. On the positive half-cycles, the negative voltage of 2 volts applied to the grid causes a current flow of 10 milliamperes through the plate load resistor, thus producing a voltage drop of 100 volts (by Ohm's law). On the negative half-cycles, the negative voltage of 4 volts applied to the grid causes a current flow of 6 milliamperes through the plate-load resistor, and a corresponding voltage drop of 60 volts. The difference between these two voltage drops, or 40 volts, is the voltage variation in the plate circuit produced by the AC voltage applied to the grid. Thus it can be seen that a signal voltage change from —1 to +1 (or a total change of 2 volts) can produce a voltage change of 40 volts in the plate circuit; in other words, the original (grid) signal voltage has been amplified 20 times. This process is the basis for all vacuum-tube amplification.

The use of a resistor as the plate load of a vacuum tube has one disadvantage; its resistance will reduce the actual DC voltage applied to the plate of the tube, and so reduce the amplification of the tube. To overcome this loss in plate voltage, inductors are often used as plate loads of vacuum-tube circuits (Figure 5-20B). By choosing an inductor which has a high value of reactance at the frequency of the alternating current, a large voltage will be built up across the reactance, because of the plate-current changes in the tube. However, the DC plate voltage applied to the plate of the tube will be quite high, since the DC resistance of an inductor may be very small, and consequently the amplification of the tube will be increased.

If it is desired to amplify a signal of a given frequency, a tuned circuit which resonates at this frequency may be used for a plate load (Figure 5-20C). Since the impedance of such a circuit will be very high at the resonant frequency, the signal voltage appearing across the tuned circuit will also be high. By using a tuned circuit as the plate load for a vacuum tube, it is possible to obtain the amplification only at the resonant frequency of the tuned circuit. The circuit of Figure 5-20C is typical of the r-f amplifier circuits used in radio transmitters.



(A) Cathode resistor bias
(1) Shunt arrangement
(2) Series arrangement.
(B) Grid-leak bias circuits

Figure 5—21. Vacuum Tube Self Bias Circuits.

9. VACUUM TUBE BIASING METHODS

There are several different methods of obtaining a negative grid-bias voltage for a vacuum tube. The simplest of these is the fixed bias, where suitable negative voltage is obtained from a fixed source, such as batteries or a rectifier power supply. Examples of this type of bias are shown in Figure 5-20.

A vacuum-tube circuit can be arranged to produce its own bias, and such a method is known as "self-bias." One type of self-biasing, called the "cathode-return-resistor bias," is shown on a triode-amplifier circuit in Figure 5-21A. In this circuit, the plate current from the battery flows through the cathode resistor on its way through the tube and back to the battery through the plate-load resistor. Since the current flows through the cathode resistor toward the cathode, there is a voltage drop across this resistor which makes the grid negative with respect to the cathode. This is the proper condition for biasing. The convenience of this type of bias is obvious, since it eliminates the need for a separate source of bias voltage. For this reason, cathode-resistor bias is widely used. Omission of the shunt capacitor, or too small a value of this capacitor, produces less amplification or degeneration as a result of the variations of grid bias which then accompany the AC pulsations of the plate current. This capacitor should have a low reactance at the signal frequency, thus keeping the cathode resistor from dropping the AC signal voltage as well as the DC plate voltage.

Another form of self-bias is called "grid-leak bias," and is used under conditions where grid current flows. Two examples of this type of bias are shown in Figure 5-21B. The bias results from the drop in potential across the resistor when grid current flows on positive AC signal swings. This resistor is called a "grid-leak." The capacitor across the leak offers a low impedance to alternating current, so that the bias is essentially steady in character and is a function of only the magnitude or size of the grid current. A disadvantage of grid-leak bias is that if for any reason the excitation is removed, the bias is removed also, and the plate current may assume dangerous proportions, causing damage to the vacuum tube.

To combine the advantage of grid-leak and battery (or fixed) bias, transmitter amplifiers often use a combination of both types in series. Some types of amplifier tubes are conveniently designed, as regards bias supply, to operate with the grid at cathode potential; these are known as "zero-bias" tubes.

10. TRIODE CHARACTERISTIC CURVES

There are two general types of characteristic curves for triodes. One is for the case of no load in the plate circuit, and is called the "static characteristic curve"; the other is for

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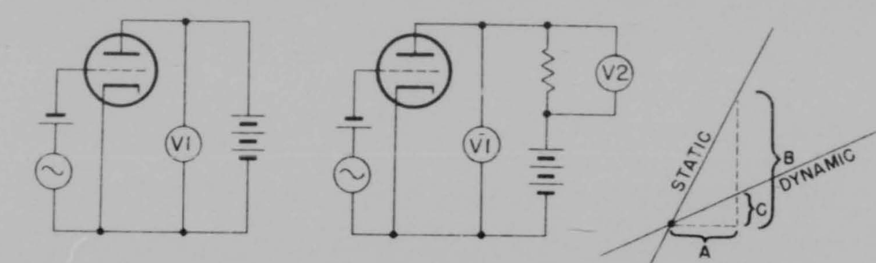
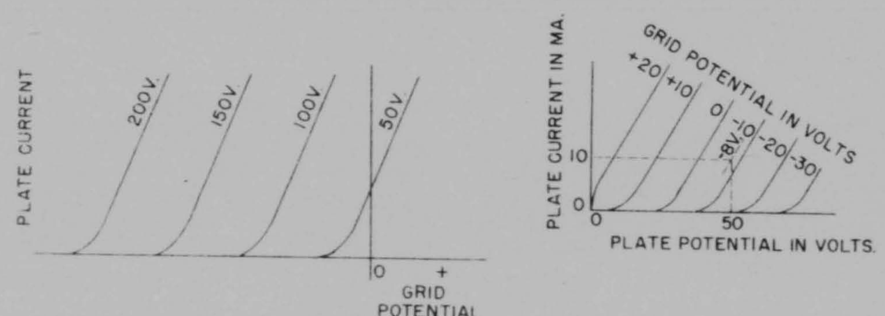


(A) Without external load. (B) With external load. (C) Corresponding characteristics

Figure 5–22. Triode Characteristic Curves.



(A) Plate current vs grid potential curves for triode.

(B) Plate current vs plate-voltage curves for a triode.

Figure 5–23. Triode Characteristics.

the case of a load in the plate circuit, and is known as the "dynamic characteristic curve." Use has already been made of the static curve in Figure 5-18B, where the tube was operating without a plate load. In practice, however, the output of a tube feeds into some sort of load which can be represented by a resistance value (assumed to be the equivalent of the load). This results in dynamic characteristic curves that reflect more accurately the operating conditions of the tube. A comparison of the static and dynamic curves, with the two circuits that are used to obtain each, is shown in Figure 5-22. The difference in the slope of the two curves is due to the fact that the plate-to-cathode potential for no load is constant regardless of the plate current, whereas with a load in the plate circuit, the potential across the load (and consequently the plate-to-cathode potential) varies with the current. Assume that the normal operating point is the same for the tube with or without external load; that is, regard the operating point as the point of intersection of the two curves of Figure 5-22C. Without an external load (Figure 5-22A) on a positive swing of signal potential A (Figure 5-22C), the plate current rises by an amount B. With an external load (Figure 5-22B), the increase in current which follows a positive grid swing is in turn accompanied by a potential drop ($I \times R$) across the load resistor (as read by voltmeter V_2). Thus the potential available across plate to cathode within the tube (as read by voltmeter V_1) is reduced; and the consequent increase in current C is less than it was under the no-load

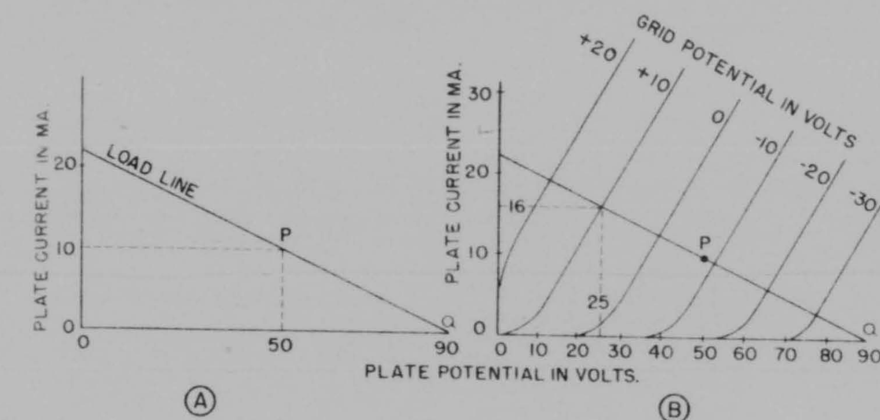


Figure 5–24. Load Line for a Triode.

condition. On the negative half-cycle of the signal voltage, the plate current is reduced, and the potential drop across the load is less than it is when no signal is applied. Thus the voltage across the tube rises, so that the available plate-to-cathode potential exceeds the corresponding value under the no-load condition. A typical set of static plate-current grid-voltage curves for various plate potentials is shown in Figure 5-23A. Many handbooks on vacuum tubes confine the characteristics illustrated to families of curves of the static type.

Observe from the set of static characteristic curves of Figure 5-23B, that of the three quantities, grid potential, plate potential, and plate current, any two will determine the third. Thus, corresponding to a plate current of 10 milliamperes and a plate potential of 50 volts, the required grid potential is —8 volts. Assuming that it is desired to obtain these same relations—plate current, 10 milliamperes; plate potential, 50 volts; and grid potential —8 volts—with a load resistance of 4,000 ohms. This requires a total plate-supply potential of $50 + (4{,}000 \times 10/1{,}000)$ volts = 90 volts, 50 across the tube and 40 across the load resistance. The current in the load resistance follows Ohm's law; that is, the current through the resistance is proportional to the potential across it. This proportionality is represented by a straight line on the current-voltage graph of Figure 5-24. The line is determined by any two points on it, two convenient points being P and Q, as in Figure 5-24A. P is for a current of 10 milliamperes and a voltage drop across the resistance of 40 volts (50 volts across the tube); Q is for zero current and zero drop across the resistance (90 volts across the tube). If P is taken as the normal operating point, the grid swing due to an impressed signal voltage will cause variations along this load line in both directions from P. Corresponding to an instantaneous grid potential of 10 volts, the plate current, plate voltage, and voltage across the load can be found by following the 10-volt characteristic to where it intersects the load line. From the curves of Figure 5-24B, this yields 16 milliamperes plate current, 25 volts plate potential, and 90—25 = 65 volts drop across the load. The family of plate-current plate-potential curves is thus useful in determining the limitations of a particular tube under various operating conditions. A particular tube can be selected to fit certain circuit constants, or vice versa, with the aid of the information contained in the vacuum-tube characteristics.

11. SPECIAL CHARACTERISTICS OF VACUUM TUBES

Since many different types of vacuum tubes are used in modern radio circuits, it is important to have different means of classifying these tubes according to the performance which may be expected of them. Among these characteristics, are the amplification factor, the mutual conductance, and the plate resistance of the tube.

The amplification factor μ, or mu, of a tube is the ratio of the plate-voltage change to the grid-voltage change required to produce the same plate-current change in the tube. For example, if the plate voltage of a tube must be increased by 20 volts in order to increase the plate current as much as would a 1-volt change of grid voltage, then the tube has an amplification factor of 20. The amplification factor of a tube is stated for a given set of operating conditions, such as grid-bias voltage, plate voltage, etc., since the amplification factor will change if these conditions are changed. The amplification factor of a tube gives a theoretical approximation of the maximum voltage amplification which can be expected from the tube under given operating conditions.

The mutual conductance, or transconductance of a tube is a characteristic from which the power sensitivity can be estimated, since it determines what plate-current change may be expected from a given grid-voltage change under a given set of operating conditions. Mutual conductance, or transconductance, is the ratio of a small change in plate current to the change in grid voltage producing it. It is measured in mhos, which is simply the word ohm spelled backwards and with an "s" added. For example, if a grid-voltage change of 1 volt produces a plate-current change of 1 ampere in a given tube under certain operating conditions, the tube will have a mutual conductance of 1 mho. But since very few tubes will stand a plate current flow of 1 ampere (receiving tubes draw only a few milliamperes of plate current), it is more convenient to rate mutual conductance in micromhos (or millionths of a mho). Thus, if a tube has a mutual conductance of 5,000 micromhos, a 1-volt change in grid voltage will produce a 5-milliampere change in plate current.

The plate resistance of a tube is simply the resistance between the cathode and plate of the tube to the flow of alternating current. It is the ratio between a small change in plate voltage and the corresponding change in plate current. For example, if a 10-volt change in plate voltage produces a 1-milliampere change in plate current, the plate resistance of the tube is 10,000 ohms.

12. INTERELECTRODE CAPACITANCE

The inherent capacitance between grid and plate elements of a triode is of sufficient importance at high frequencies to require special consideration in radio circuits. Where this capacitance is undesirable, it can be counteracted by introducing a neutralizing circuit which presents r-f potentials equal in magnitude but opposite in phase to those occurring across the interelectrode capacitance, with the result that the effects of the interelectrode capacitance are nullified. The extra circuit complications can generally be avoided by the use of tetrodes or pentodes, 4- and 5-element tubes, respectively, which are particularly designed to have low interelectrode capacitance. The grid-plate capacitance of an ordinary receiving triode runs about 3 micromicrofarads. This represents a capacitance reactance of 53,000 ohms at 1 megacycle and only 530 ohms at 100 megacycles. Tetrodes and pentodes offer corresponding reactances of about 16,000,000 ohms at 1 megacycle and 160,000 ohms at 100 megacycles.

13. THE TETRODE

In an effort to reduce the grid-plate capacitance within the tube, a fourth element was added to the conventional triode. This fourth element is called a screen grid, and is placed between the grid and the plate of the tube. A typical screen grid, or tetrode (4-element) tube connected in a circuit is shown in Figure 5-25. In observing the changes in this circuit due to the addition of the screen grid, it is noted that the screen grid is operated at a positive voltage somewhat lower than that which is applied to the plate. Since it is operated at a positive voltage, the screen assists the plate in attracting electrons from the cathode. Some of these electrons are attracted to this grid by the positive voltage on it, thus causing screen current to flow in the circuit. However, since the construction of the screen grid is similar to that of the control grid, most of the electrons pass through the spaces between its wires to the plate, because of the attraction of the higher positive voltage on the plate. Since the screen grid is bypassed to the negative side of the circuit (bypassed to ground) by a screen-bypass capacitor having a small reactance at the signal frequency, it acts as a shield, or screen, between the grid and the plate, and thus effectively reduces the capacitance between these two electrodes.

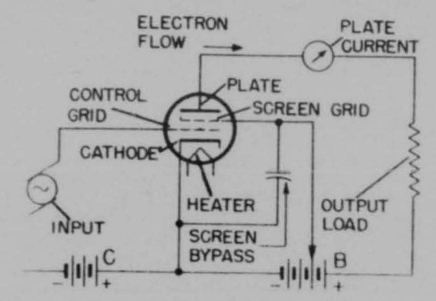


Figure 5–25. Tetrode Amplifier Circuit.

If the screen grid in this circuit is not operated at a positive voltage, but is connected to the cathode, it will have a controlling effect on the electron flow, similar to that of the control grid of the tube, thus reducing the plate-current flow to a value too small for satisfactory operation. The value of a positive voltage on the screen grid of a tetrode will determine, to a large extent, the maximum value of current which will flow in the plate circuit. Thus, improper screen voltages can cause faulty operation in tetrode-amplifier circuits.

The tetrode has several advantages over the triode, in addition to its greatly reduced grid-plate capacitance. Among these are a higher amplification factor, and greater power sensitivity. In general, tetrodes can be used for the same purpose as triodes. Since they were developed to overcome the need for neutralization in r-f amplifier circuits, tetrodes have been widely used in the amplifier stages of radio receivers and transmitters.

14. THE PENTODE

Although the tetrode would seem to be an ideal tube, since it overcomes the disadvantage of the higher grid-plate capacitance of the triode, and, at the same time, is capable of providing higher amplification in a circuit than is the triode, the effect known as "secondary emission" limits its application to a great extent. The pentode, or 5-element tube, was developed to overcome the effect of secondary emission. If a tetrode is operated at fairly high plate and screen voltages, and large values of signal voltage are applied to its control grid, the electrons strike the plate with sufficient force to knock loose other electrons already on the surface of the plate. These other electrons, known as "secondary electrons," are attracted by the positive voltage on the screen grid. When secondary emission occurs, the screen gets more than its share of the available electrons, while the number reaching the plate is greatly reduced. Thus, the screen current will increase while the plate current will decrease, causing a reduction in the amplification of the tube and distortion in its output.

If a third grid is placed between the screen grid and the plate of the tetrode, and is connected to the cathode, so that it has the same charge as the electrons, it will force any secondary electrons back to the plate, since like charges repel one another. This third grid is called the "suppressor grid," since it suppresses the effects of secondary emission by preventing the flow of secondary electrons to the screen. The suppressor grid will not reduce the electron flow to the plate, even though it is operated at a negative potential. This is because it is placed so close to the plate that the attraction of the positive voltage on the plate is much greater than any tendency on the part of the suppressor grid to repel the electrons.

Although the effect of secondary emission is usually a nuisance, it has been found useful in the operation of certain oscillators such as the dynatron.

15. VARIABLE-MU TUBE

The amplification of a tube is controlled by varying the bias voltage applied to the grid, but normally the range of this control is limited by the value of cutoff bias for the tube. It is most desirable in the r-f amplifiers of receivers, the gain of which is controlled by automatic volume control, to be able to vary the amplification over a much wider range so that large values of signal voltage (strong signals) may be handled. To permit this increased range of gain control, the variable-mu tube has been developed. This type of tube is also known by several other names, two of which are supercontrol and remote cut-off. The only difference in construction between variable-mu tubes and normal, or sharp cut-off types, is the spacing of the grid turns. In sharp cutoff tubes, the turns of the grid wire are equally spaced, while in remote cutoff types, the grid turns are closely spaced on both ends and widely spaced in the center. When small negative voltages are applied to the grid of a variable-mu tube, the electrons will flow through all the spaces in the grid. As the negative voltage is increased, however, the electrons will no longer be able to pass through the narrow spaces on the ends of the grid structure, although they will still be able to pass through the relatively greater spaces at the center of the grid. A much greater value of negative voltage will thus be required to cut off the plate-current flow in this type of tube. This remote cutoff tube is so named because the cutoff bias value is greater than (remote from) the value required to cut off plate-current flow in a tube of evenly spaced grid turns.

Figure 5-26 shows the E_G—I_P curves for a typical sharp cutoff pentode and a typical remote-cutoff pentode on the same graph. Note that the cutoff bias for the tube with the uniformly spaced grid is —6 volts. Thus the range of gain control which can be effected by grid-bias variation, and the maximum value of signal voltage which can be applied to the grid, are both limited. But the curve for the super control pentode shows that plate current still flows even at a grid bias of —24 volts. Thus, by the use of a variable-mu tube, both the range of gain control by grid bias

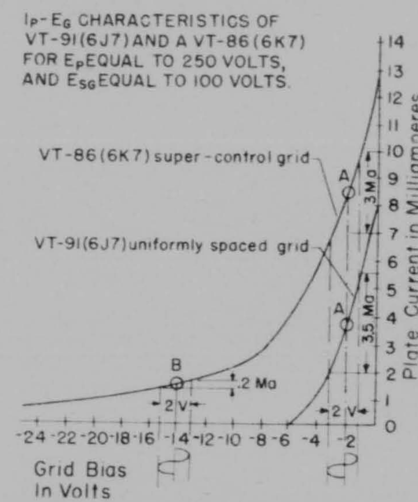


Figure 5–26. Comparison Between a Sharp Cut-Off Pentode and a Remote Cut-Off Pentode.

variation and the value of signal voltage which can be handled by the grid have been extended several times.

16. BEAM-POWER TUBE

In recent years, a new type of power-amplifier tube has been developed. Compared with other tetrode and pentode power-amplifier tubes, this tube has the advantages of higher power output, higher power sensitivity, and higher efficiency. This type of tube is called the "beam-power" tube, because by its construction the electrons are caused to flow in a concentrated beam from the cathode, through the grids, to the plate. The only difference in construction between the beam-power tube and normal tetrodes and pentodes is that the spaces between the turns of the several grids are lined up and two beam-forming plates are added. Figure 5-27 shows the internal construction of a beam-power tetrode. Since the spaces between the turns of the grids are lined up, fewer electrons will strike the screen grid. The screen current will therefore be decreased, while the plate current will be increased. Since the power output of a circuit is proportional to the value of plate current flowing through the load, the power output will thus be increased. The two beam-forming plates are usually connected to the cathode, and, having the same charge as the electrons, cause them to flow in a beam from the cathode, through the grids, to the plates. The placement of the beam-forming plates is such that it forces the electrons to flow through the desired portion of the grids, and prevents them from striking the wires which support the grids. Thus, by causing the electrons to flow in a beam, the number of electrons reaching the plate can be increased, thereby greatly increasing the operating efficiency of the tube.

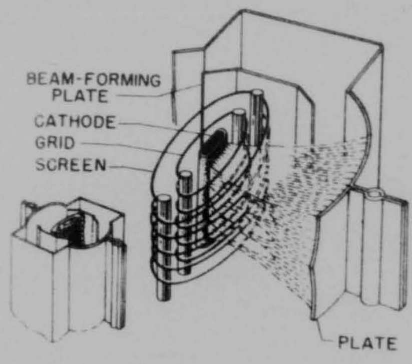


Figure 5–27. Internal Structure of a Beam-Power Tube.

A beam-power tube operated at the same voltages as a normal tetrode or pentode type will provide more power output for a given value of signal (input) voltage than the latter, and have a much higher plate-circuit efficiency. In beam tetrodes, the effect of secondary emission is reduced to a minimum by the action of the beam. Both beam tetrodes and beam pentodes are used in receivers and transmitters.

17. MULTI-ELEMENT TUBES

In addition to the diodes, triodes, tetrodes, and pentodes, there are many special types of vacuum tubes used in radio circuits; a large number of types are used which combine the electrodes of two or more tubes in one envelope. These complex tubes are usually named according to the equivalent single-tube types of which they are composed. Thus a twin triode contains the electrodes for two triodes in one envelope. Other complex tubes are diode-triodes, diode pentodes and triode pentodes. **All of these tubes, however complex, follow the basic rules for tube operation. To understand the operation of any one of them in a circuit, it is only necessary to consider the effect of the various electrodes on the flow of electrons within the tube.**

The pentagrid-converter tube is a special type which has five grids, and is used for frequency conversion in the superheterodyne receiver.

18. MERCURY-VAPOR TUBES

The space charge of electrons in the vicinity of the cathode in a diode causes the plate-to-cathode voltage drop to be a function of the current flowing between the cathode and the plate. This voltage drop can be rather high when large currents are being passed, causing a considerable amount of energy loss which shows up as plate dissipation. However, this negative space charge can be neutralized by the presence of the proper density of positive ions in the space between the cathode and plate. These positive ions can be obtained by the introduction of mercury into the tube. When a filament is heated, the mercury vapor pressure within the tube increases to such a value that the electron flow between cathode and plate will ionize enough mercury vapor to neutralize the space charge. Since the ionization potential of mercury vapor under these conditions of temperature and pressure is between 10 and 15 volts, the voltage drop across a mercury-vapor rectifier is substantially constant at this voltage regardless of the current carried up to the maximum rating of the tube.

Mercury-vapor tubes have the disadvantage, however, that they must be operated within a specified temperature range (25° to 70° C), in order that the mercury vapor pressure within the tube be within the proper range. If the temperature is too low, the drop across the tube becomes too high, causing im-

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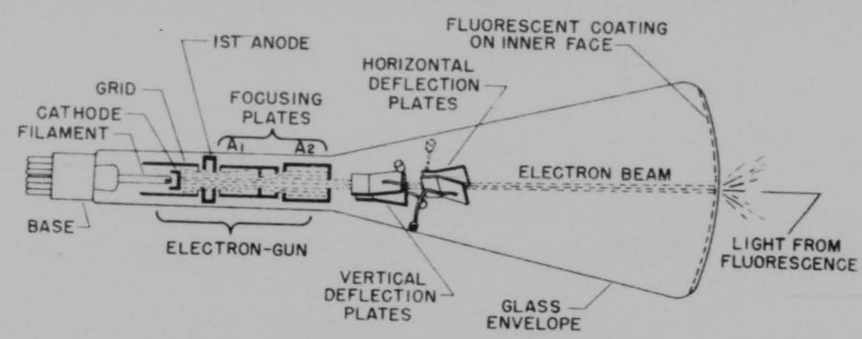

Figure 5–28. Simplified Construction of Typical Cathode-Ray Tube.

mediate overheating and possible damage to the elements. If the temperature is too high, the vapor pressure is too high, and the voltage at which the tube will "flash back" is lowered to the point where destruction of the tube may take place. Since the ambient temperature range specified above is within the normal room temperature range, no trouble will be encountered under normal operating conditions. However, by the substitution of xenon gas for mercury, it is possible to produce a rectifier with characteristics comparable to those of the mercury-vapor tube, except that the tube is capable of operating over the range from approximately —70° to 90° C. Since these tubes are more expensive than mercury-vapor rectifiers, their use is recommended only when extremely low or unusually high temperatures are likely to be encountered in the vicinity of the tubes.

19. THYRATRON TUBES

If a grid is inserted between the cathode and plate of a mercury-vapor gaseous-conduction rectifier, a negative potential placed upon the added element will increase the plate-to-cathode voltage drop required before the tube will ionize or "fire." The potential upon the control grid will have no effect on the plate-to-cathode drop after the tube has ionized. However, the grid voltage may be adjusted to such a value that conduction will take place only over the desired portion of the cycle of the AC voltage being impressed upon the plate of the rectifier.

20. COLD-CATHODE TUBES

Cold-cathode tubes are devices in which, as the name would imply, external heating of the cathode is not necessary to initiate current flow between cathode and plate. Such tubes are available both in the form of diodes and triodes, and always have a certain amount of controlled gas content. Initial breakdown of the gas within the tube is caused, after anode voltage is applied, by the high potential gradient between a point, which serves as the cathode, and an element of much larger area which serves as the anode or plate. It always takes a certain amount more voltage between cathode and anode to initiate the discharge than to sustain it continuously.

The most commonly used cold-cathode tubes are the VR-tube series of voltage regulators. The application of these tubes to the problem of voltage regulation is discussed in the following section. In addition to the cold-cathode diodes, or VR tubes, several cold-cathode triodes are available. In these tubes, the ionic discharge within the gas is initiated by the application of an r-f or AC voltage of 50 to 100 volts peak to a starter anode. These tubes are normally used in remote control devices where it is desired that no energy be taken by the controlled device until it is desired that the controlled device be completely operative.

21. THE CATHODE-RAY TUBE

The construction of a typical cathode-ray tube is illustrated in the pictorial diagram of

Figure 5-28. The indirectly heated cathode releases free electrons when heated by the enclosed filament. The cathode is surrounded by a cylinder which has a small hole in front for the passage of the electron stream. Although this element is not a wire mesh as is the usual grid, it is known by the same name because its action is similar; it controls the electron stream when its negative potential is varied.

Next in order is found the first accelerating anode, which resembles another disk, or cylinder, with a small hole in its center. This electrode is run at a high or moderately high positive voltage, to accelerate the electrons toward the far end of the tube. The focusing electrode, A_1, is a sleeve which usually contains two small disks, each with a small hole.

After leaving the focusing electrode, the electrons pass through another accelerating anode, A_2, which is operated at a high positive potential. In some tubes, this electrode is operated at a higher potential than the first accelerating electrode; while in other tubes, both accelerating electrodes are operated at the same potential.

The electrodes which have been described up to this point constitute the "electron gun," which produces the free electrons and focuses them into a slender, concentrated, rapidly-traveling stream for projection onto the viewing screen.

To make the tube useful, means must be provided for deflecting the electron beam along two axes at right angles to each other. The more common tubes employ electrostatic deflection plates, one pair to exert a force on the beam in the horizontal plane and one pair to exert a force in the vertical plane.

Certain of the cathode-ray tubes employ magnetic deflection, utilizing an electromagnet in the form of a yoke to deflect the electron beam. However, this discussion will be confined to those tubes which use electrostatic deflection.

The fact that the beam is deflected by a magnetic field is important even in an oscilloscope which employs a tube using electrostatic deflection, because it means that precautions must be taken to protect the tube from the transformer fields and sometimes even the earth's magnetic field. This normally is done by incorporating a magnetic shield around the tube and by placing any transformers as far from the tube as possible, orientated to the position which produces minimum effect upon the electron stream.

With most tubes, the spot will be very accurately centered if all four deflecting plates are at ground potential. However, a means of varying the DC voltage slightly on one of each pair of electrodes often is provided so as to permit accurate centering of the "spot" under all conditions.

After the spot is once centered, it is necessary only to apply a positive or negative voltage (with respect to ground) to one of the ungrounded or "free" deflector plates in order to move the spot. If the voltage is positive with respect to ground, the beam will be attracted toward that deflector plate, while if negative, the beam and spot will be repulsed. The amount of deflection is directly proportional to the voltage (with respect to ground) that is applied to the free electrode.

With the larger-screen higher-voltage tubes, it becomes necessary to place deflecting voltage on both horizontal and both vertical plates. This is done for two reasons: First, the amount of deflection voltage required by the high-voltage tubes is so great that a transmitting tube operating from a plate supply of 1500 to 2000 volts would be required to attain this voltage without distortion. By using push-pull deflection with two tubes feeding the deflection plates, the necessary plate supply voltage for the deflection amplifier is halved. Second, a certain amount of defocusing of the electron stream is always present on the extreme excursions in deflection voltage when this voltage is applied only to one deflecting plate. When the deflecting voltage is fed in push-pull to both deflecting plates in each plane, there is no defocusing because the average voltage acting on the electron stream is zero, even though the net voltage (which causes the deflection acting on the stream) is twice that on either plate.

Cathode-ray tubes are obtainable with any one of several types of screen material, each having its characteristic "persistence" and

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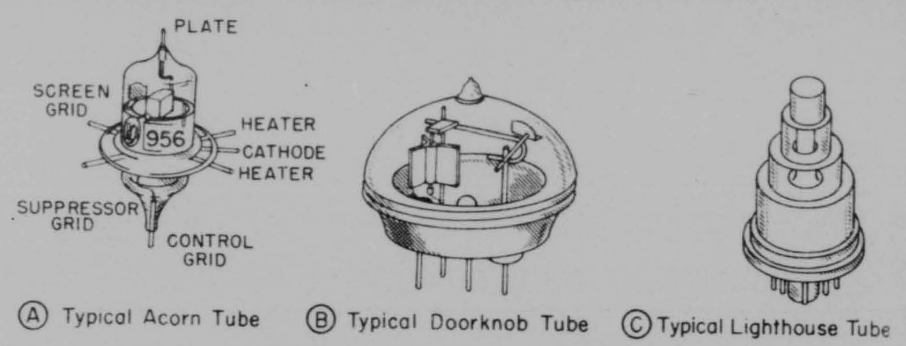

Figure 5—29. VHF Vacuum Tubes.

fluorescent color. The persistence is the degree to which the screen material will glow after being bombarded with electrons. The fluorescent material will give off light for an instant after the bombardment is terminated, and the longer the time, the longer the persistence.

22. SPECIAL VACUUM TUBES FOR U-H-F USE

The most suitable vacuum tubes for u-h-f use are those having low interelectrode capacitance, close spacing of the electrodes to reduce transit time, a high amplification factor, and a low or medium optimum value of load impedance. While some of these requirements are necessarily conflicting, tubes have been produced which are well adapted for u-h-f operation. The "lighthouse," "acorn," and "doorknob" tubes are examples of this type (Figure 5-29). The "doorknob" tube is simply a larger version of the "acorn."

23. SPECIAL VACUUM TUBES FOR U-H-F AND S-H-F USE

Two special type tubes necessary for u-h-f and s-h-f radar are the magnetron and klystron; the magnetron being used in radar transmitters and the klystron in the receivers.

The magnetron is an s-h-f oscillator tube normally employed where very high values of peak power or moderate amounts of average power are required in the range of from perhaps 700 Mc. to 100,000 Mc. In its simplest form, the magnetron tube is a filament-type diode with two half-cylindrical plates or anodes situated coaxially with respect to the filament. The construction is illustrated in Figure 5-30A. Under the influence of the strong magnetic field, electrons leaving the filament are deflected from their normal paths and move in circular orbits within the anode cylinder (Figure 5-30B). This effect results in a negative resistance which sustains oscillations.

Complex magnetron tubes employ no external tuned circuit, but utilize instead one or more resonant cavities which are integral with the anode structure. Figure 5-31 shows a magnetron of this type having a multicellular anode of eight cavities. It will be noted also that alternate cavities (which would operate at the same polarity when the tube is oscillating) are strapped together. Strapping was found to improve the efficiency and stability of high-power radar magnetrons. In most radar applications of magnetron oscillators, a powerful permanent magnet rather than an electromagnet is employed to supply the magnetic field.

The **klystron** is a specialized microwave tube which depends upon velocity modulation of an electron stream for its operation. In various sizes, this tube is employed as a voltage amplifier, power amplifier, superheterodyne oscillator or mixer, detector, and frequency multiplier. The klystron removes the

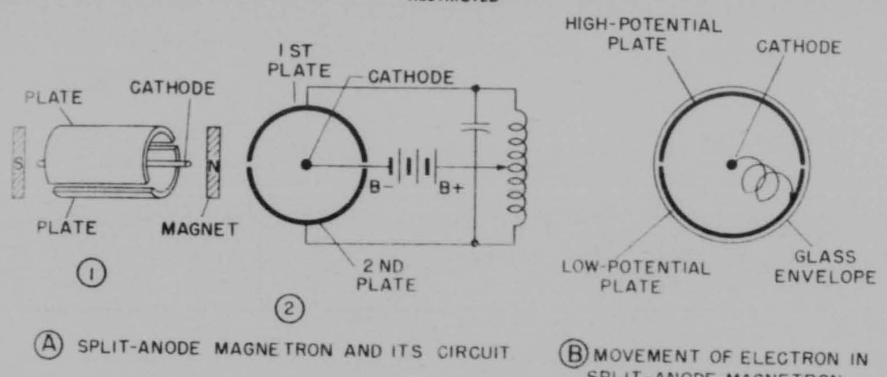

Figure 5—30. Simple Magnetron Tube.

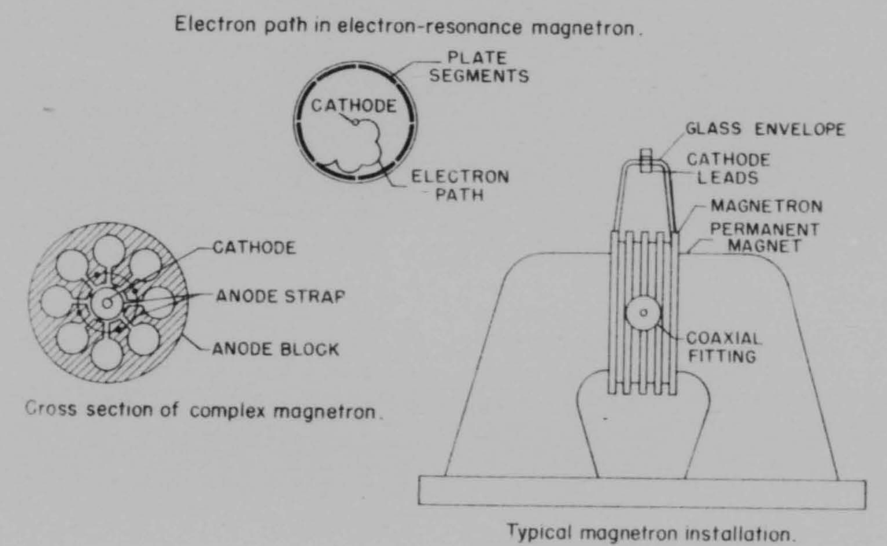

Figure 5—31. Complex Magnetron Tube.

necessity (so important in conventional grid-controlled tubes) of limiting electron transit time to a fraction of the time required for one microwave cycle.

The klystron is an electron-coupled device. When used as an oscillator, its output voltage is rich in harmonics. Klystron oscillators of various types afford power outputs ranging from less than one watt to several hundred watts. Tuning is done mechanically in some klystrons by altering (by means of knob settings) the shape of the resonant cavity.

In addition to heater, cathode, and control grid (which, together form an electron gun),

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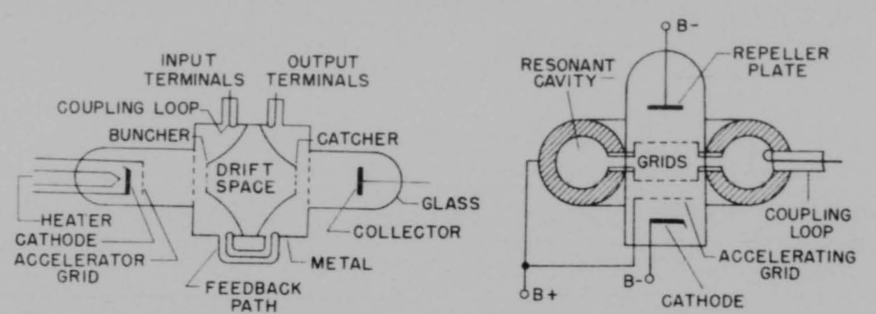

(A) Klystron tube with cavity resonator.

(B) Schematic diagram of a reflex klystron

Figure 5—32. Klystron Tubes.

and a collector plate, two cavity resonators of reentrant shape are included in the klystron tube. One of these, known as the "buncher," immediately follows the control grid. The electron beam from the gun section enters the buncher through a grid in the aperture in one of its reentrant walls, and leaves through a similar grid aperture in the other parallel reentrant wall. The second cavity, known as the "catcher," follows the buncher and has a similar pair of grids in its own parallel reentrant walls. Buncher and catcher are mounted back to back to provide a drift space for the electron beam passing from one cavity to the other.

The electron beam from the gun comes under the influence of the electrostatic field between the two buncher grids as the beam passes through the buncher apertures. The grid field is oscillating if the buncher cavity is being excited by oscillating energy, and this field is parallel to the electron beam which it acts alternately to accelerate and retard. The beam thus becomes velocity-modulated.

When the electron beam reaches the drift space, where there is no field, those electrons which have been sped up on one-half cycle overtake those immediately ahead which were slowed down on the other half-cycle. In this way, the beam electrons become bunched together. As the bunched groups pass through the two grids of the catcher cavity, they impart some of their energy to these grids. The catcher grid-space is charged to different voltage levels by the passing electron bunches, and a corresponding oscillating field is set up in the catcher cavity. The catcher is designed to resonate at the frequency of the velocity-modulated beam.

The two-cavity klystron (Figure 5-32A) as described in the preceding paragraphs is primarily used as a transmitting device since quite reasonable amounts of power are made available in its output circuit. However, for applications where a much smaller amount of power is required—power levels from milliwatts to a watt or two—for low-power transmitters, receiver local oscillators, etc., another type of klystron having only a single cavity is more frequently used.

The theory of operating of the single-cavity or reflex klystron is essentially the same as the multi-cavity type with the exception that the velocity-modulated electron beam, after having left the "buncher" cavity is reflected back into the area of the buncher again by a repeller electrode as illustrated in Figure 5-32B. The potentials on the various electrodes are adjusted to a value such that proper bunching of the electron beam will take place just as a particular portion of the velocity-modulated beam re-enters the area of the resonant cavity. Since this type of klystron has only one circuit it can be used only as an oscillator and not as an amplifier. Effective modulations of the frequency of a single-cavity klystron for FM work can be obtained by modulating the repeller electrode voltage.

SECTION III—ELECTRONIC CIRCUITS

1. POWER SUPPLIES

General

Any device which incorporates vacuum tubes requires a power supply for the filament and plate circuits of the tubes. The filaments must be heated in order to produce a source of electrons; direct-current voltages are needed for the other electrodes in order to obtain amplification, oscillation, and some methods of detection.

Either AC or DC voltage may be used for filament power supply in most applications. The plate potential is secured from a DC source, such as from batteries or from a rectified and filtered AC power supply.

First the AC must be converted into a unidirectional current; this is accomplished by means of a rectifier of either the full- or half-wave type.

Half-wave Rectifier. A half-wave rectifier (Figure 5-33A) passes one half of the wave of each cycle of the alternating current and blocks the other half. The output current is of a pulsating nature, which can be smoothed into pure, direct current by means of filter circuits. Since half-wave rectifiers produce a pulsating current which has zero output during one half of each AC cycle, it is difficult to filter the output properly into pure DC and to secure good voltage regulation for varying loads.

Full-wave Rectifier. A full-wave rectifier consists of a pair of half-wave rectifiers working on opposite halves of the cycle, connected in such a manner that each half of the rectifier AC wave is combined in the output as shown in Figure 5-33B. This pulsating unidirectional current can be filtered to any desired degree, depending upon the particular application for which the power supply is designed.

Bridge Rectifier. The bridge rectifier (Figure 5-33C) is a type of full-wave circuit in which four rectifier tubes are operated from a single high-voltage winding of the power transformer. While twice as much output voltage can be obtained from a bridge rectifier as from a center-tapped circuit, the permissible output current is only one-half as great for a given power transformer.

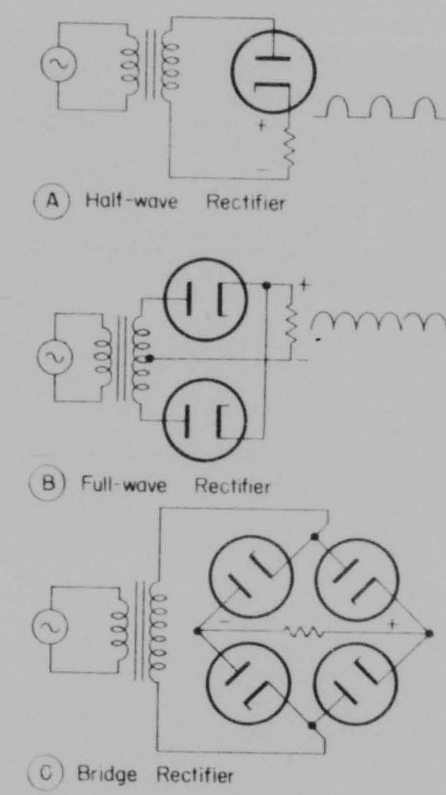

Figure 5—33. Typical Rectifier Circuits.

Filters. The filter circuit for a conventional power supply (Figure 5-34) consists of a low-pass section whose cutoff frequency is lower than the minimum ripple or pulsating fre-

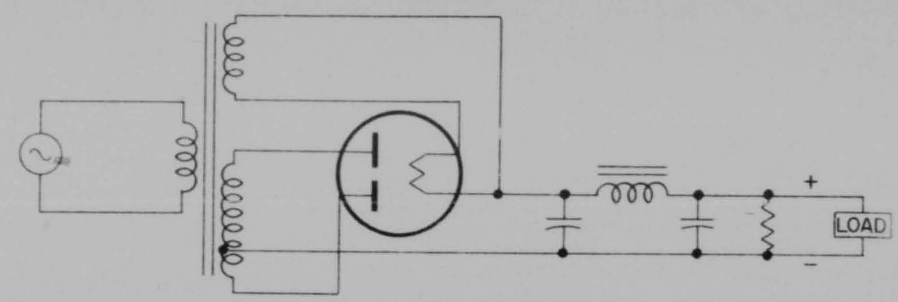

Figure 5–34. Full-Wave Rectifier and Filter.

quency to be expected from the power supply. An electric current always follows the path of least resistance of impedance. The direct-current component of the rectifier output will travel through the choke coil and back to the return path through the external load which normally consists of the plate circuits or vacuum tubes. The AC component of the rectifier output, however, tends to be impeded by the choke and short-circuited by the parallel capacitors so that the amount of alternating current at the output of the filter is very much less than that at the input.

Filter inductors consist of a coil of wire wound on a laminated iron core. The size of the wire is determined by the amount of direct current which is to flow through the choke coil.

Filter capacitors are of two types. Either the paper dielectric or the electrolytic type may be used. Paper capacitors possess the advantage of withstanding high breakdown potentials and reduced leakage currents, but are physically much larger and bulkier than the electrolytic type of capacitor.

A heavy duty resistor (bleeder) should be connected across the output of a filter in order to draw some load current at all times. This resistor avoids soaring of the voltage at no load, and also provides a means for discharging the filter capacitors when no external load is connected to the circuit.

Voltage Regulators (Figure 5-35)

Where it is desired in a circuit to stabilize the voltage supply to a circuit requiring no more than 25 milliamperes, a glow-discharge type of voltage-regulator tube may be used.

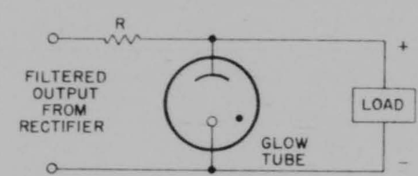

Figure 5–35. Glow-Tube Voltage Regulator.

The OC3 VR-105 and OD3 VR-150 are of this type. When it is desired to stabilize the potential across a circuit drawing more than a few milliamperes, a more complex electronically-regulated power supply must be used.

Voltage Doubler (Figure 5-36)

Another type of rectifier circuit, called a "voltage doubler," is sometimes used in special applications. This circuit, in effect, charges two filter capacitors separately across a source of voltage and then discharges them in series through the load. The output voltage is therefore approximately twice the input voltage.

2. AMPLIFIERS

General

The ability of the control grid of a vacuum tube to control large amounts of plate power with a small amount of grid energy allows the vacuum tube to be used as an amplifier. It is this ability to amplify an extremely small amount of energy up to almost any level without change in anything except amplitude which makes the vacuum tube such an ex-

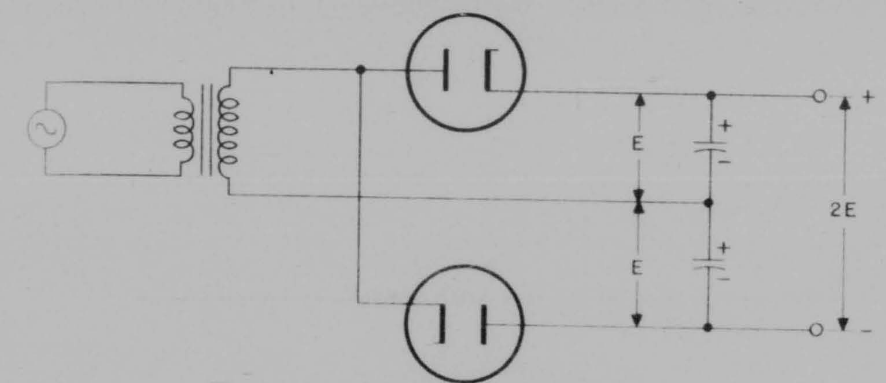

Figure 5–36. Voltage-Doubler Power Supply.

tremely valuable adjunct to modern electronics and communications.

Voltage and Power Amplifiers

Every amplifier circuit may be classified as either a voltage or a power amplifier. Voltage amplifiers are designed to provide a maximum amount of voltage amplification, but usually cannot deliver an appreciable amount of current or power to a load. Since many electrical loads (radio loudspeaker, cathode-ray tube deflection coils, or a radar antenna system) represent a low impedance and therefore absorb power from the driving source, a power amplifier is generally used. A complete amplifier system usually consists of several voltage amplifiers and a power amplifier. The number of voltage amplifier stages employed depends upon the amount of amplification required in order to raise the signal level to a voltage which will properly drive the grid of the power amplifier.

Amplifier systems are also classified according to the range of frequencies which they are intended to handle. That is, audio amplifiers operate within a frequency range of 15 to 15,000 cycles per second; video amplifiers from 15 cycles to approximately 4 megacycles per second; and a radio frequency amplifier will amplify any group of frequencies above 15,000 cycles per second. Any one of these amplifiers may be of the voltage or power-amplifier type.

Classes of Amplifiers

Vacuum-tube amplifiers are grouped into classes according to the type of work they are to perform. The difference between the various classes is determined primarily by the value of average grid bias employed and the maximum value of the exciting signal to be impressed upon the grid.

A class A amplifier is an amplifier biased and supplied with excitation of such amplitude that plate current flows continuously and grid current does not flow at any time. Such an amplifier is normally operated in the center of the grid-voltage, plate-voltage, plate-current transfer characteristic and gives an output waveshape which is a substantial replica of the input waveshape.

A class AB amplifier is operated under such conditions of grid bias and exciting voltage that plate current flows for more than one-half the input voltage cycle but for less than the complete cycle. The suffix 1 may be added in order to indicate that grid current does not flow over any portion of the input cycle.

A class AB_2 amplifier is operated under essentially the same conditions of grid bias as the class AB_1 amplifier, but the exciting voltage is of such amplitude that grid current flows over an appreciable portion of the input wave cycle.

A class B amplifier is biased substantially to cutoff of plate current (without exciting

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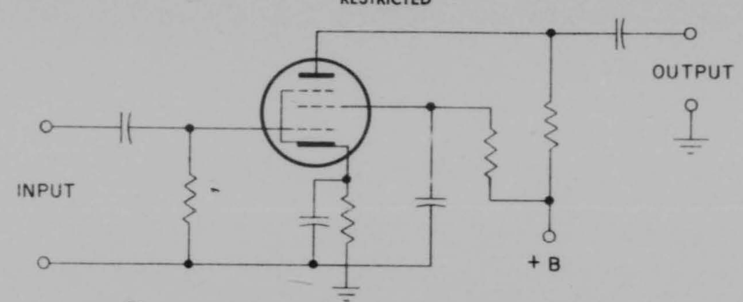
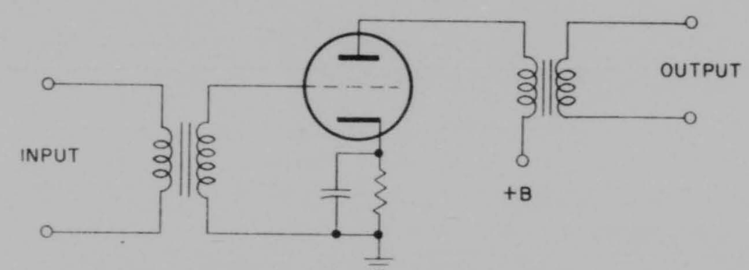


(A) Resistance Coupled Amplifier



(B) Transformer Coupled Amplifier

Figure 5—37. Resistance and Inductance Coupled Amplifiers.

voltage) so that plate current flows essentially over one-half the input voltage cycle. It is almost always excited to such an extent that grid current flows.

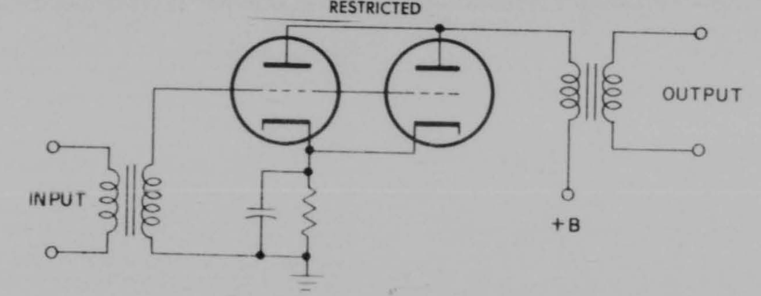
A class C amplifier is biased to a value greater than the value required for plate current cutoff and is excited with a signal of such amplitude that grid current flows over an appreciable period of the input voltage waveshape. The plate current flows appreciably less than one-half the time.

Voltage amplifiers are almost invariably operated class A, while power amplifiers may be of any class. Although class A power amplifiers introduce the least amount of distortion to the incoming waveshape, their use is limited since the plate efficiency is low. This is due to the continuous flow of plate current, even in the absence of a signal on the grid.

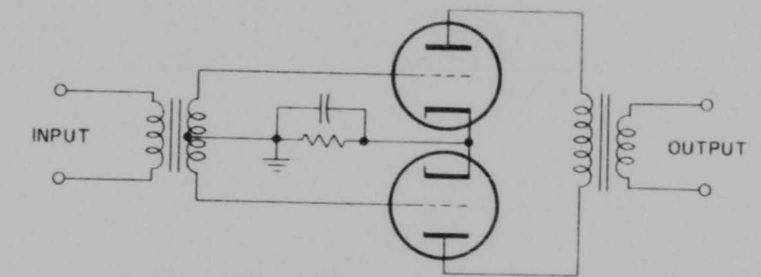
Class AB, B and C amplifiers are used largely in high-powered high-efficiency circuits. However, since plate current flows for only a brief portion of the input cycle to a class C amplifier, it can be used only in equipments where fidelity of the output waveshape is not important.

Resistance Coupled Amplifiers. Any type of amplifier may also be designated by the type of load included in its plate circuit (Figure 5-37A). That is, a resistance coupled amplifier employs a load resistor in the plate circuit of the vacuum tube. The output is usually coupled to the following stage by means of a DC blocking capacitor. Voltage amplifiers are often the resistance coupled type.

Transformer coupled amplifiers (Figure 5-37B) substitute the primary of a transformer for the load resistor that was used in the resistance coupled amplifier circuit. This type of circuit is widely used in power-amplifier equipment since it is possible to match the dynamic impedance of the vacuum tube to the load impedance by employing a transformer with the proper turns ratio. An



(A) Parallel Amplifiers.



(B) Push-Pull Amplifiers.

Figure 5—38. Parallel and Push-Pull Amplifiers.

impedance match is necessary in order to secure maximum power transfer.

Either push-pull or parallel operation of power tubes may be employed to obtain increased output (Figure 5-38). The parallel connection (Figure 5-38A) provides twice the output of a single tube with the same value of grid-signal voltage. The push-pull or paraphase connection (Figure 5-38B) requires twice the input-signal voltage, but has, in addition to an increase in power, a number of important advantages over single tube operation. Distortion due to even order harmonics and hum due to plate-supply-voltage fluctuations are either eliminated or decidedly reduced through cancellation. Since distortion is less than for single tube operation, appreciably more than twice single-tube output can be obtained by decreasing the load resistance.

Audio amplifiers may be transformer-coupled, impedance coupled, or resistance-coupled. Video-frequency amplifiers are usually resistance-coupled amplifiers as their gain characteristics must be flat over a very wide frequency range. Intermediate and radio-frequency amplifiers are designed ordinarily for tuned-circuit coupling, although in actual operation they may resemble either the transformer coupled or the impedance-coupled circuit.

Distortion

Three types of distortion that may occur in amplifiers are frequency distortion, phase distortion, and amplitude or nonlinear distortion.

Distortion which occurs when some frequency components of a signal are amplified more than others is known as "frequency distortion." Most coupling circuits shift the phase of a sine wave, but this has no effect on the shape of the output. However, when more complex waveshapes are amplified, each component frequency of the waveshape may be shifted by different amounts so that the output is not a faithful representation of the input waveshape. This is known as "phase distortion."

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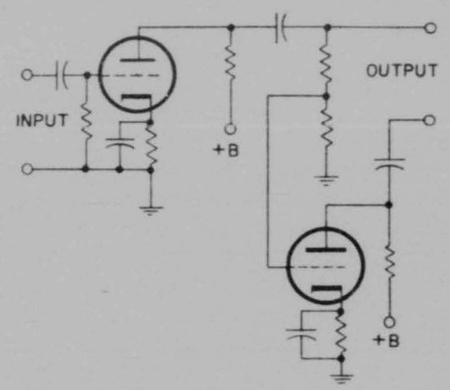

Figure 5–39. Phase Inverter.

If a signal is passed through a vacuum tube that is operating on any nonlinear part of its characteristic, amplitude distortion will occur.

Radio-frequency Amplifiers

In a tuned amplifier, part of the coupling circuit is a parallel resonant circuit. Because of the selective properties of the resonant circuit tuned amplifiers are used as radio-frequency and intermediate-frequency amplifiers where a narrow band of frequencies is to be amplified and all other frequencies eliminated.

Inverse Feedback

An inverse-feedback circuit, sometimes called a degenerative circuit, is one in which a portion of the output voltage of a tube is applied to the input of the same or a preceding tube in opposite phase to the signal applied to the tube. Two important advantages of feedback are: reduced distortion from each stage included in the feedback circuit; reduction in the variations of gain due to changes in line voltage, possible differences between tubes of the same type, or variations in the values of circuit constants included in the feedback circuit.

Phase Inversion

A phase inverter is a circuit (Figure 5-39) used to provide resistance coupling between the output of a single-tube stage and the input of a push-pull stage. The necessity for a phase inverter arises because the signal-voltage inputs to the grids of a push-pull stage must be 180 degrees out of phase and approximately equal in amplitude with respect to each other. Thus, when the signal voltage input to a push-pull stage swings the control grid of one tube in a positive direction, it should swing the other grid in a negative direction by a similar amount. With transformer coupling between stages, the out-of-phase input voltage to the push-pull stage is supplied by means of the center-tapped secondary. With resistance coupling, the out-of-phase input voltage is obtained by means of the inverter action of a tube.

Gain Measurement

When voltage amplifier stages are operated in such a manner that the output voltage of the first is fed to the grid of the second, and so forth, such stages are said to be "cascaded." The total voltage gain of cascaded amplifier stages is obtained by taking the product of the voltage gains of each of the successive stages.

Inasmuch as the ear and eye respond logarithmically to variations in sound and light intensity, any unit used to compare such levels must, in order to be practical, vary logarithmically. Such a unit is the decibel. The abbreviation for decibel is db. The total db gain of cascaded amplifier stages is obtained by taking the sum of the db gains of each of the successive stages. The average person would not notice a change in a radio-program level of less than 3 db.

3. GENERATION OF RADIO-FREQUENCY ENERGY

General

An oscillator is a nonrotating type of AC generator. A vacuum tube and its associated components replace the mechanical type of alternator. A negative-grid type of oscillator is essentially a vacuum tube amplifier with a sufficient portion of the output energy coupled back into the input circuit to sustain oscillation. The control grid is biased a considerable amount negative with respect to the cathode.

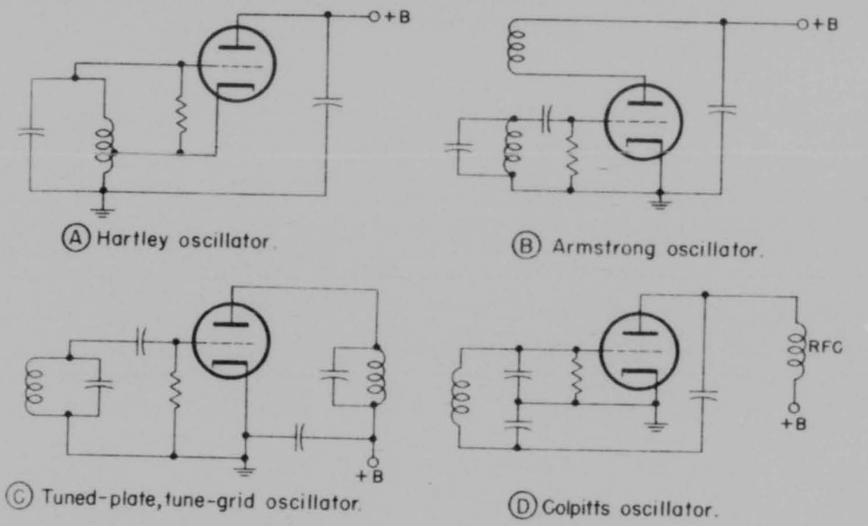

Figure 5–40. Negative Grid Oscillators.

This oscillator finds most common application in low- and medium-frequency transmitter circuits. Common types of negative-grid oscillators are diagrammed in Figure 5-40.

The operation of each of these oscillators (Hartley, Colpitts, T.P.T.G.) is fundamentally the same. The essential differences involve the methods employed to obtain regenerative feedback.

Theory of Operation

When plate voltage is applied to the Hartley oscillator shown in Figure 5-40A, the sudden flow of plate current accompanying the application of plate voltage will cause an electro-magnetic field to be set up in the vicinity of the coil. The building-up of this field will cause a potential drop to appear from turn-to-turn along the coil. Due to the inducive coupling between the portion of the coil in which the plate current is flowing and the grid portion, a potential will be induced in the grid portion.

Since the cathode tap is between the grid and plate ends of the coil, the induced grid voltage acts in such manner as to increase further the plate current of the tube. This action will continue for a short period of time determined by the inductance and capacitance of the tuned circuit, until the flywheel effect of the tuned circuit causes this action to come to a maximum and then to reverse itself. The plate current then decreases, the magnetic field around the coil also decreasing, until a minimum is reached, when the action starts again in the original direction and at a greater amplitude than before. The amplitude of these oscillations, the frequency of which is determined by the coil-capacitor circuit, will increase in a very short time to a limit determined by the plate voltage or the cathode emission of the oscillator tube.

In any of the oscillator circuits just illustrated (Figures 5-40B, C, D) it is possible to take energy from the oscillator circuit by coupling an external load to the tank circuit. Since the tank circuit determines the frequency of oscillation of the tube, any variations in the condition of the external circuit will be coupled back into the frequency determining portion of the oscillator. These variations result in frequency instability.

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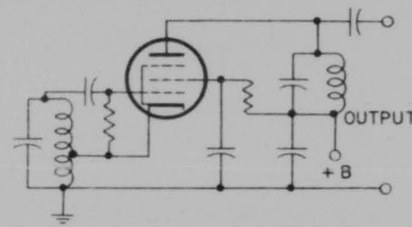

Figure 5—41. Electron Coupled Oscillator.

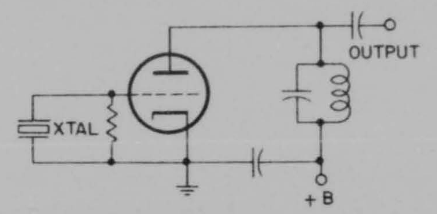

Figure 5—42. Crystal Oscillator.

Electron-coupled Oscillators

The electron-coupled oscillator (Figure 5-41) has great stability with respect to load and voltage variation. Load variations have very little effect on the frequency, since the only coupling between the oscillating circuit and the load is through the electron stream flowing through the other elements to the plate. The plate is electrostatically shielded from the oscillating portion by the bypassed screen.

The stability of the e.c.o. with respect to variations in supply voltages is explained as follows: The frequency will shift in one direction with an increase in screen voltage, while an increase in plate voltage will cause it to shift in the other direction. By a proper proportioning of the resistors that comprise the voltage divider supplying the screen voltage, it is possible to make the frequency of the oscillator substantially independent of supply voltage variations.

Quartz Crystal Oscillators

Quartz and tourmaline are naturally occurring crystals having a structure which, when plates are cut in certain definite relationships to the crystallographic axes, will show the piezo-electric effect—the plates will be deformed in the influence of an electric field, and, conversely, when such a plate is compressed or deformed in any way a potential difference will appear upon its opposite sides.

The crystal has mechanical resonance, and will vibrate at a very high frequency because of its stiffness, the natural period of vibration depending upon its dimensions and crystallographic orientation. Because of the piezo-

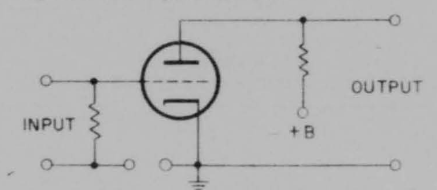

Figure 5—43. Direct-Current Amplifier.

electric properties, it is possible to cut a quartz plate which, when provided with suitable electrodes, will have the characteristics of a parallel resonant circuit with a very high Q. The Q is several times as high as can be obtained with an inductor-capacitor combination in conventional physical sizes. This parallel resonant characteristic permits the crystal to be used in place of an L C tank in an oscillator (Figure 5-42) with greatly increased stability as a result of the much higher Q.

4. SPECIAL CIRCUITS

DC Amplifiers

Direct-current amplifiers (Figure 5-43) are special types used where amplification of very slow variations in voltage or of DC voltages is desired. A simple DC amplifier consists of a single tube with a grid resistor across the input terminals, and with the load in the plate circuit. The load may be some sort of mechanical device such as a relay, a meter, or a counter, or the output voltage may be used to control the gain of an amplifier.

The DC voltage to be amplified must be applied directly to the grid of the amplifier tube.

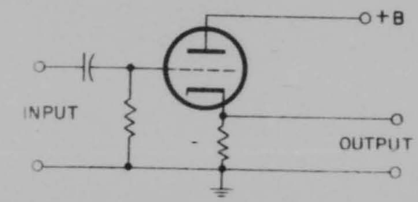

Figure 5—44. Cathode Follower.

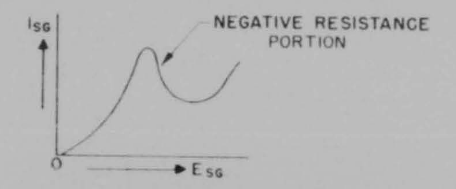

Figure 5—45. Screen-Current vs Screen Voltage Characteristic of a Pentode with Screen-Suppressor Coupling.

Therefore, direct coupling is required in the input circuit.

Cathode Followers

The cathode follower (Figure 5-44) is a degenerative vacuum-tube circuit in which the inverse feedback is obtained by way of an unbypassed cathode resistor, across which the output is taken. This circuit is essentially an impedance-matching or impedance-lowering device having less than unity voltage gain but capable of producing power gain. Its high input impedance and very low output impedance render it particularly suitable for coupling between pulse-generating or pulse-transmitting stages and transmission lines of circuits with shunt capacitance which otherwise might cause objectionable effects. The cathode-follower output "follows" the grid-input voltage and hence is of the same polarity. The output voltage of a cathode follower has good regulation because of its low impedance while the input voltage to the cathode follower may have a high impedance and very poor regulation.

The output of one unit of equipment often must be fed through a coaxial cable which may be, in some cases, as long as fifty feet. Such a cable, because of its distributed capacity, inductance and resistance, represents at the output an impedance which is much lower than the output impedance of a conventional amplifier. A cathode follower designed with a low impedance output can deliver much more of its output through such a line than can a conventional amplifier.

Transitron Oscillator (negative GM)

Figure 5-45 shows that the characteristic curve of screen current vs screen voltage of a pentode in which the screen is coupled to the suppressor has a portion with negative slope. Between the screen and screen supply, therefore, such a circuit may act like a negative resistance, and sustained sinusoidal oscillations may occur in an LC tank inserted in the screen circuit. Such an oscillator is called a "transitron" or "negative transconductance oscillator" (Figure 5-46).

Resistance-capacitance Oscillators

In an R-C oscillator, the frequency is deter-

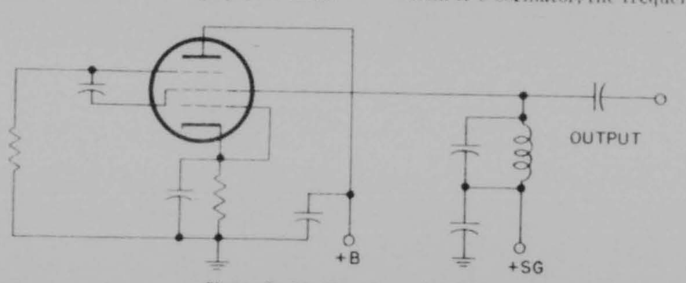

Figure 5—46. Transitron Oscillator.

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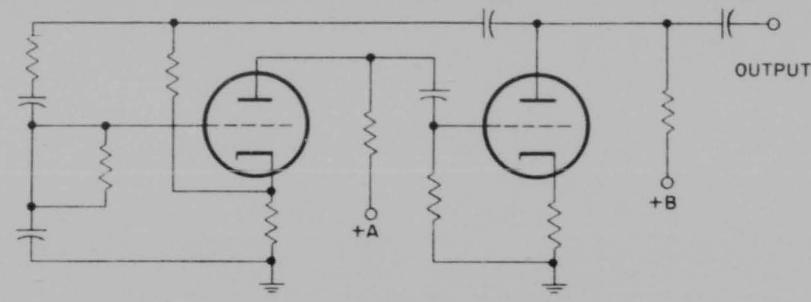

Figure 5—47. Wein-Bridge Oscillator.

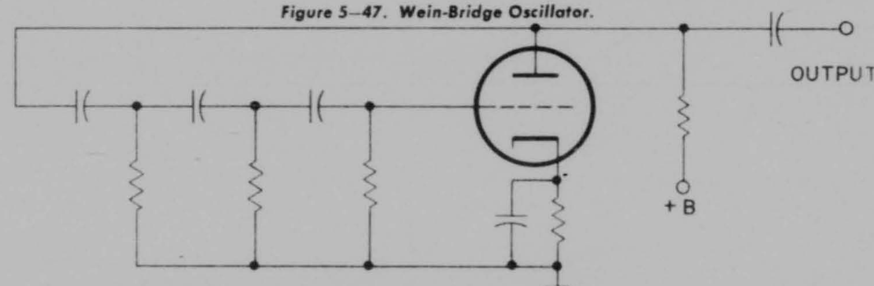

Figure 5—48. Phase-Shift Oscillator.

mined by a resistance-capacitance network which provides regenerative coupling between the output and input of a feedback amplifier. No use is made of a tank circuit consisting of inductance and capacitance to control the frequency.

Wien Bridge

An oscillator in which a frequency-selective Wien-bridgé circuit is used as the resistance-capacitance feedback network is called a "Wien-bridge oscillator." One widely used circuit for this type of oscillator is shown in Figure 5-47.

The bridge allows a voltage of only one frequency to be effective in the circuit because of the degeneration and phase shift provided by this circuit. The Wien-bridge oscillator has many advantages over other types of audio-frequency oscillators. For instance, it may conveniently be made to produce a wide range of frequencies. The waveshape is very nearly a true sine wave. Frequency stability is excellent. Finally, the output amplitude is nearly constant over a very wide frequency range.

Phase-shift Oscillator

The phase-shift oscillator is a special type of resistance-capacitance-tuned oscillator that operates with a single tube. The circuit consists of only one amplifier tube plus a phase-shifting feedback circuit which creates a phase shift in proportion to the frequency passed through it (Figure 5-48). The standard feedback-oscillator circuit requires that the signal from the plate be shifted 180 degrees in order that reinforcing action can take place on the grid to make up for circuit losses. In the phase-shift oscillator this is accomplished by three resistance-capacitance sections.

Limiting Circuits

The term "limiting" refers to the removal by electronic means of one extremity or the other of an inout wave. Circuits which perform this function are referred to as "limiters" or "clippers."

Limiters are useful in waveshaping circuits where it is desirable to square off the extrem-

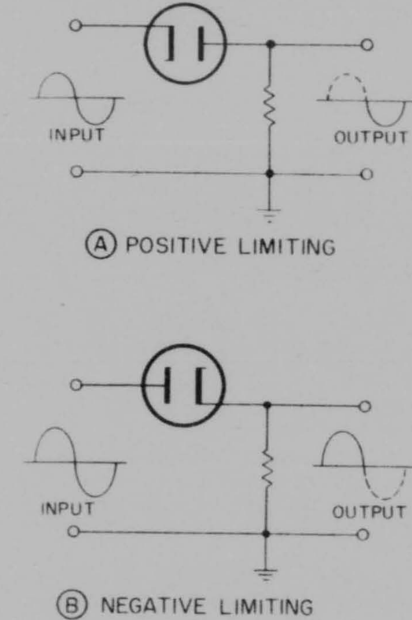

Figure 5—49. Typical Series Limiting Circuits.

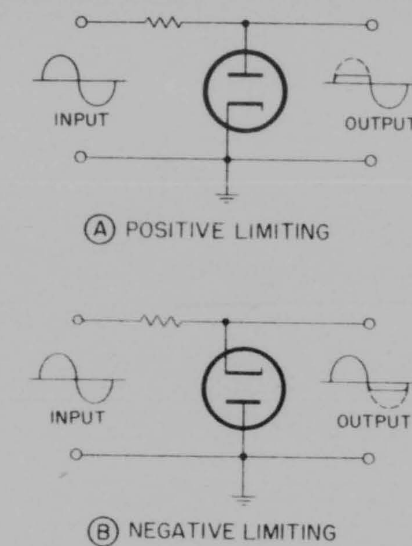

Figure 5—50. Typical Parallel Limiting Circuits.

ities of the applied signal. A sine wave may be applied to a limiter circuit to obtain a rectangular wave. A peaked wave may be applied to a limiter to eliminate either the positive or the negative peaks from the output. In frequency modulation receivers, where it is necessary to limit the amplitude of the signal applied to the detection system to a constant value, limiter circuits are employed. Limiters find application as protective devices in circuits in which the input voltage to a stage must be prevented from swinging too far in the positive or the negative direction.

Series-diode Limiting

The characteristics of a diode are such that the tube conducts only when the plate is at a positive potential with respect to the cathode; in other words, when the cathode is negative with respect to the plate.

The series-diode limiter shown in Figure 5-49A is commonly used to limit the positive half of a sine wave. The rectifying characteristics of the diode are utilized so that it may be considered as a switch. Thus, the output voltage remains at zero throughout the positive half cycle of the input since the diode switch is open and no current flows through R. During the negative half cycle, on the other hand, the cathode is negative with respect to the plate and the tube conducts.

In a similar manner, the same circuit, with the diode connections reversed, may be used to limit the negative swing of the input voltage. This application is illustrated in Figure 5-49B.

Parallel-diode Limiting

An alternate method of employing diodes in limiter circuits is shown in Figure 5-50. The tubes in the two circuits are connected in parallel with the load, which is assumed to be a very high impedance so that the output current is negligible.

In Figure 5-50A, the diode is connected so as to limit the positive signals at approximately ground potential. Since the cathode is held at ground potential, the diode conducts

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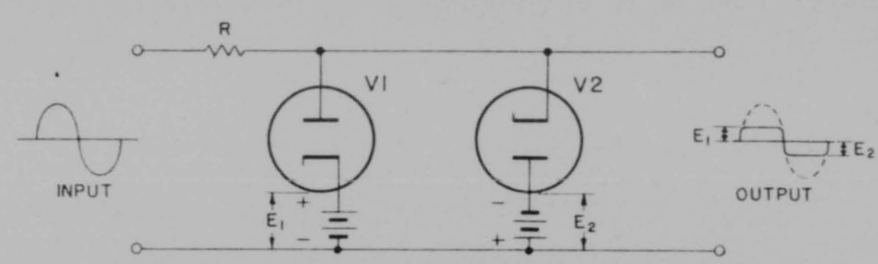

Figure 5—51. Double-Diode Limiter.

throughout the entire positive half cycle. Current flows through the tube and through the series resistor R. As R is large as compared to the plate-to-cathode resistance of the diode, essentially the entire input voltage is developed across R and the output voltage is only the very low voltage drop across the diode. On the negative swing of the input, the diode does not conduct; thus no current flows through R and the output voltage equals the input.

In Figure 5-50B, the plate of the diode is held at ground potential so that the tube does not conduct during the positive half cycle. Thus the output voltage equals the input. During the negative half cycle of the input voltage, the cathode is negative with respect to the plate and the diode conducts. The diode current flows through the series resistance R across which essentially the entire input voltage is developed. The output voltage is limited to the very low voltage drop across the tube. This low negative voltage as a rule may be neglected, and, in this and the previous examples, the outputs may be considered as being limited at essentially ground potential as a result of the switching action of the diode.

An input voltage can be limited to any desirable positive or negative value by holding the proper diode electrode at that voltage by means of a battery or a biasing resistor.

Double-diode Limiting

It is possible to limit both amplitude extremities of an input waveform at any desirable levels by placing two diodes in parallel in the limiter circuit. The circuit (Figure 5-51) represents a simple method of producing a satisfactory square-wave output with a sine-wave input voltage.

Grid Limiting

The grid-cathode of a triode, tetrode or pentode may be employed as a limiter circuit in exactly the same way as the plate-cathode circuit of the diode limiter illustrated in Figure 5-51.

The grid limiter circuit shown in Figure 5-52 is held normally at zero bias. During the positive portion of the input signal the grid attempts to swing positive. Grid current flows through the resistor R, developing drop of such polarity as to oppose the positive input voltage. The drop may be considered as an automatic bias developed during the part of the input which causes grid current to flow.

Cutoff Limiting

Electron current through a vacuum tube can flow only from cathode to plate and not from plate to cathode. Therefore, a plate current cannot become a negative value. When the grid is driven to cutoff, the plate current is decreased to zero and remains at zero during the time the grid is below cutoff. Since no current flows through the plate circuit when the tube is cut off, no voltage is developed across the load resistance and the plate is maintained at the full value of the plate-supply voltage. Thus a type of limiting is achieved in which the positive extreme of the plate waveform is flattened as a result of driving the grid beyond cutoff.

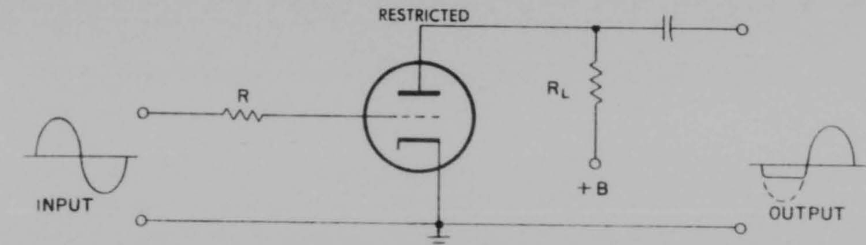

Figure 5—52. Unbiased Grid-Limiter.

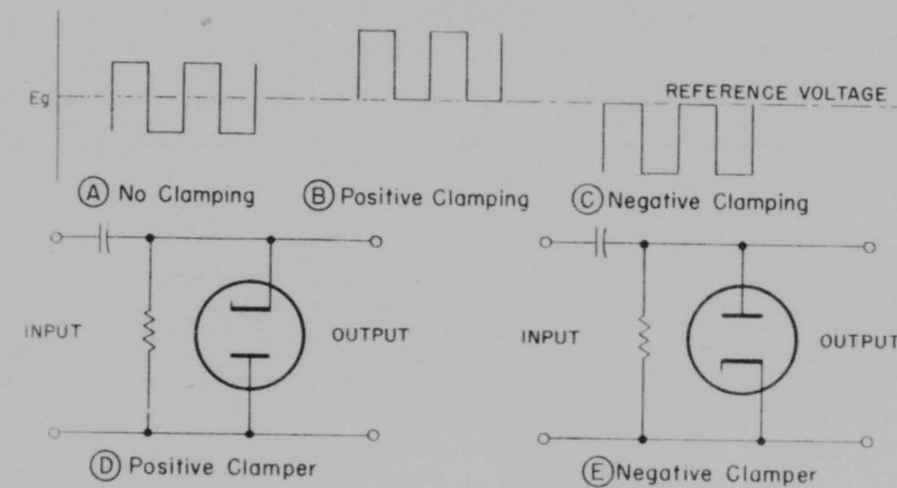

Figure 5—53. Clamping Circuits and Waveforms.

Saturation Limiting

The grid-limiting resistor may be omitted, if the input signal comes from a low-impedance high-power source, and limiting in the plate circuit may still be realized. This is due to plate-current saturation and is usually referred to as "saturation limiting." Plate-current saturation should not be confused with emission saturation since in tubes using oxide-coated cathodes there is no definite saturation value of emission currents.

Overdriven Amplifier

An amplifier circuit in which saturation-limiting is employed in conjunction with cut-off limiting to produce a rectangular wave from a sine wave is generally known as an "over-driven amplifier." The driving circuit for such an amplifier should have a relatively low-output impedance and be capable of delivering power, as considerable current is drawn during the positive swing of the grid.

Limiter Applications

In radar work, very narrow pulses often are required to start oscillators into action, to force grids above cutoff so that the tube may conduct for a short period, or to modulate radio frequencies into brief pulses. Alternately positive and negative pulses, obtained in various ways, may be passed through a limiting circuit to obtain pulses which are either positive or negative with respect to a reference value. This reference level may be at zero voltage or any positive or negative potential. By alternate stages of amplification and limit-

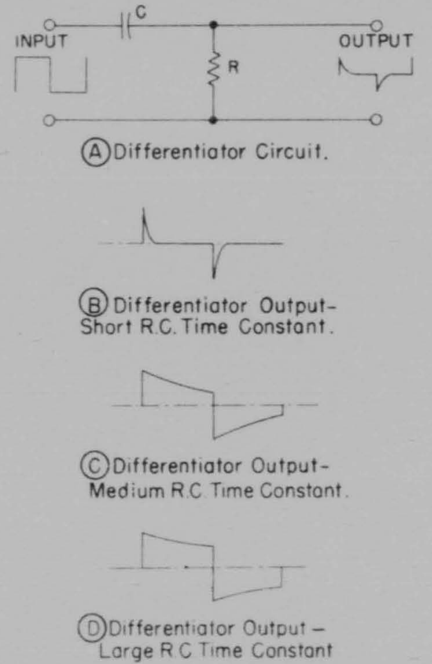

Figure 5—54. Differentiation Circuit and Waveforms.

ing, the pulse may be narrowed to any width desired.

Clamping Circuits

A circuit (Figure 5-53) which holds either amplitude extreme of a waveform to a given reference level of potential is called a "clamping circuit"; the terms "DC restorer" and "baseline stabilizer" also are commonly used.

To demonstrate the utility of clamping circuits, a brief review of the action of coupling networks is useful. In coupling between stages in radio and radar circuits, a coupling capacitor almost always must be used to keep the high positive DC plate potential of the first tube isolated from the grid of the second tube. It is desirable that only the varying component of the plate potential be transmitted to the grid as a signal varying above and below fixed reference level. If the lower end of

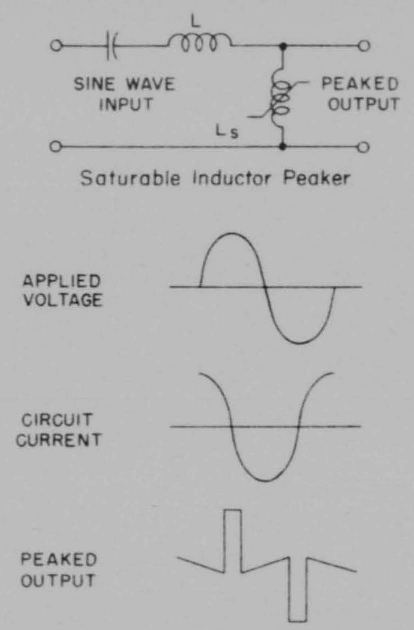

Figure 5—55. Inductive Peaking Circuit and Waveforms.

the grid-leak resistor is grounded, the signal varies about ground. If a biasing potential is employed, the signal applied to the grid varies above and below this DC bias voltage.

In other circuits, however, the waveform swing must be entirely below the reference voltage, instead of alternating on both sides of it. For these applications a clamping circuit is used to hold either the positive extreme or the negative extreme of the waveform to the desired level.

Peaking Circuits

In the development of trigger pulses for use in controlling the operation of various types of circuits, peaking circuits are often employed. As a rule, it is necessary to have a trigger pulse of very short duration and with an extremely sharp leading edge. In order to produce such pulses it is necessary to use a circuit capable of distorting an input signal in

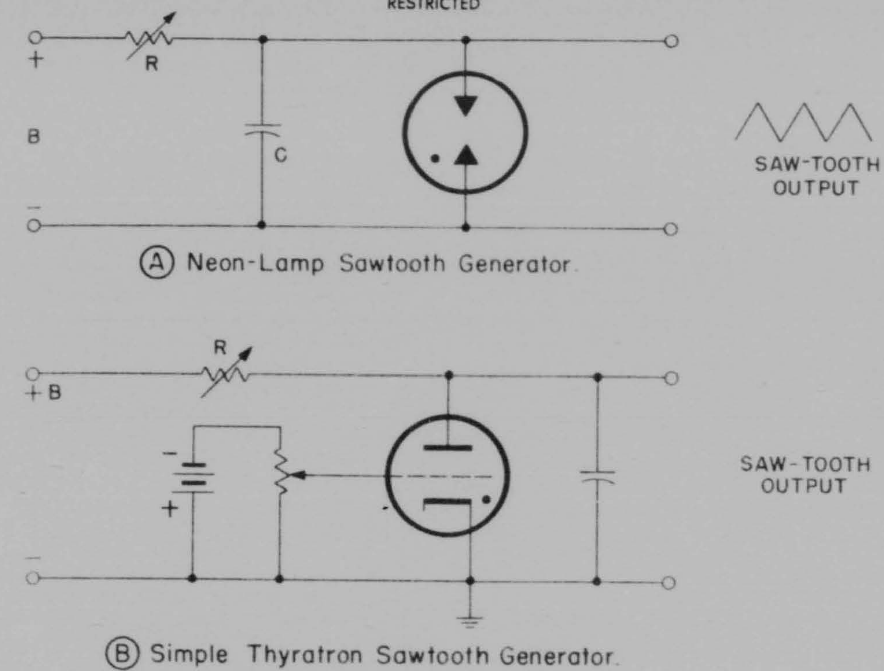

Figure 5—56. Sawtooth Generator Circuits.

such a way as to produce an output waveform in which the time duration is shortened and the leading edge is as nearly vertical as possible.

The choice of peaking circuit used depends primarily upon the kind of input signal available. If the input signal is a rectangular wave and R-C differentiator circuit is employed to produce the peaked output. An alternate method employs a transformer to produce the peaked output. If the available signal is a sine wave a saturable inductor can be used to produce the trigger pulses.

R-C Differentiator

A differentiator circuit (Figure 5-54) produces an output voltage the amplitude of which is proportional to the rate of change of the input voltage. In an R-C differentiator circuit, the time constant is made short relative to the duration of the applied pulse in order that the capacitor will become fully charged in a small fraction of the pulse duration. The charge on a capacitor cannot change in value instantaneously, but changes only at the rate established by the R-C product. This is equivalent to the statement that sudden change in the voltage of one terminal of a capacitor must occur simultaneously with an equal change in the voltage of the other terminal. Since the two circuit components act as a voltage-divider network, the portion of the applied voltage which does not appear across the capacitor, because of the time required for a change of charge, must appear across the resistor as an output voltage.

Saturable Inductor

A special coil in which a low value of current produces magnetic saturation of the core is termed a "saturable inductor." This type of inductor which is sometimes called a "nonlinear coil," can be used to produce sharp pulses directly from a pure sine wave.

An inductor (Figure 5-55) offers an impedance to the flow of alternating current because the current produces a changing flux which induces in the coil a voltage of such polarity that it resists the flow of current by opposing the applied voltage. The larger the inductance, the larger is the impedance to the flow of alternating current. In an iron-core inductor the impedance at any frequency is proportional to the inductance as long as the core is not magnetically saturated. However, when the core is saturated, the flux linking the coil can no longer be increased by an increase of the current through the coil so that the induced back voltage drops to a low value.

Sawtooth Generators

Voltages having sawtooth waveforms have wide application in radar. The simplest method of obtaining this type of waveshape is by means of a gas-tube relaxation oscillator. This oscillator is one in which no tuned circuits are employed, and the output shows abrupt changes in voltage usually brought about by charging or discharging a capacitor through a resistance.

Neon Tube Sawtooth Generator

The tube illustrated in Figure 5-56A is a neon glow tube. Until the potential across this type of tube reaches a value high enough to ionize the gas, the tube presents an almost infinite impedance. However, once ionized, a very small voltage is sufficient to keep the current flowing, and until the voltage across the tube falls below the value required to maintain the ionization, the tube has a low impedance. When the voltage falls below this value, the gas de-ionizes and current flow ceases. The potential at which the gas ionizes and conduction begins is called the "firing potential" of the tube, and that at which deionization takes place is known as "deionizing potential." The tube can be considered as a switch which is open when the tube is not ionized and closed when it is ionized.

The simplest form of sawtooth generator consists of a capacitor, a variable resistor, a source of power, and a gas-tube switch. Since the voltage across this capacitor may be controlled by the neon switch, the circuit is called a neon sawtooth generator (Figure 5-56A). When constant voltage is applied to the input of this circuit, the capacitor is charged through the resistor. The voltage across the capacitor rises from zero, approaching the full supply voltage along a normal R-C charging curve. The voltage across the neon tube is the same as the voltage across the capacitor, because these elements are in parallel. The neon tube acts as an open switch until the voltage across it reaches the firing point. At the firing potential, the neon tube ionizes and forms a discharge path for the capacitor. The capacitor thus discharges very rapidly until the voltage falls to the deionizing potential of the neon tube, when conduction stops and the tube again becomes an open switch. The capacitor then begins to charge again toward the supply voltage. The voltage rises along the R-C curve to the firing potential of the neon tube, and then falls. This process continues as long as a DC supply is maintained.

The frequency of a sawtooth wave is the number of times the voltage rises and falls per second. This frequency can be varied by changing the firing and deionizing potentials, but this means of variation requires a change in neon-tube characteristics. A simpler method of frequency control is to vary the value of the resistor, the value of the capacitor, or the magnitude of the supply voltage.

Thyratron Sawtooth Generator

This relaxation oscillation is similar in operation to the neon sawtooth generator. A thyratron tube (Figure 5-56B), or gas triode, is used as an electronic switch. The thyratron acts in the same manner as the neon tube, except that a grid has been added to control the firing potential.

Multivibrators

The multivibrator is a form of relaxation oscillator which is frequently used in radar circuits. There are several different types in use, depending on the function they are required to perform. Multivibrators may be designed as continuous or free-running or as driven oscillators whose operation and frequency is controlled by a synchronizing or triggering voltage applied from an outside source. The output of a multivibrator is usually nearly rectangular in form and the frequency may range from about 1 cycle per minute to 100 kilocycles per second.

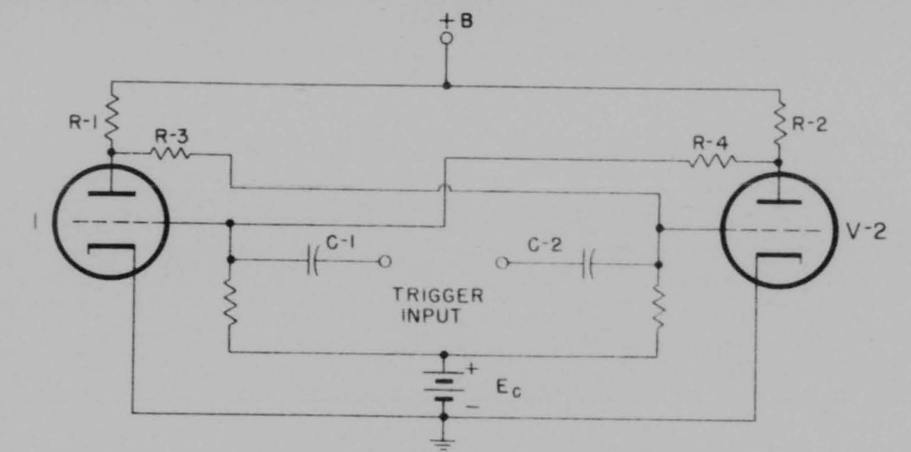

Figure 5—57. Eccles-Jordan Trigger Circuit.

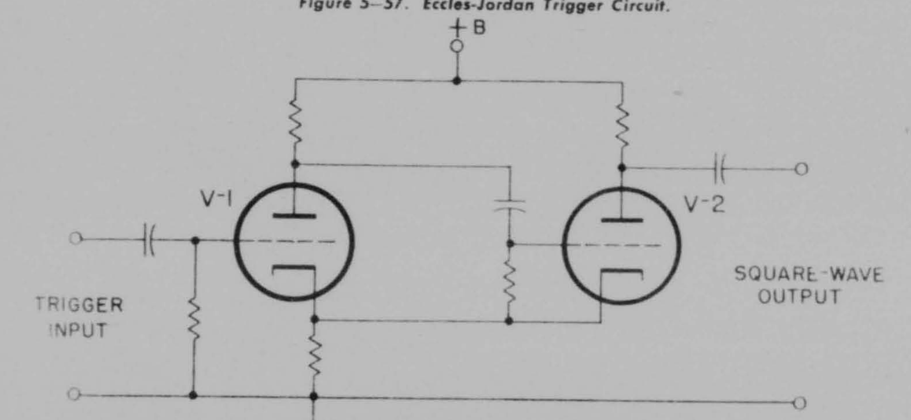

Figure 5—58. One-Slot Multivibrator.

Trigger Circuits

The multivibrator will be more easily understood if the action of the Eccles-Jordan trigger circuit is first studied. This circuit is shown in Figure 5-57. This form of multivibrator employs direct coupling between the plates and grids of the two tubes. It is not an oscillator in the true sense; rather it is a circuit possessing two conditions of stable equilibrium. One condition is when V_1 is conducting the V_2 is cut off; the other when V_2 is conducting and V_1 is cut off. The circuit remains in one or the other of these two conditions with no change in plate, grid, cathode potentials, or plate current, until some action occurs which causes the nonconducting tube to conduct. The tubes then reverse their functions and remain in the new condition as long as no plate current flows in the cutoff tube. Because of this sudden reversal of "flopping" from one state of equilibrium to the other, this type of circuit is often referred to as a "flip-flop circuit."

One-shot Multivibrators

The circuit shown in Figure 5-58 is a modi-

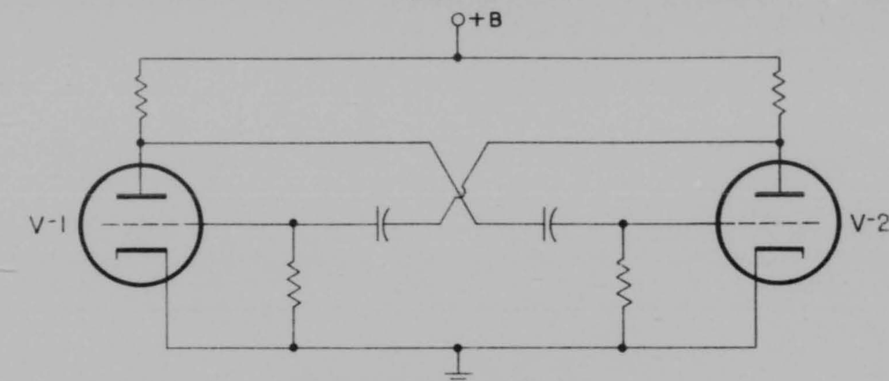

Figure 5–59. Basic Multivibrator.

fication of the Eccles-Jordan which accomplishes a complete cycle when triggered with a positive pulse. It is essentially a two-stage resistance-capacitance-coupled amplifier with one tube cut off and the other normally conducting. The balanced condition of the circuit is established by the arrangement for biasing the tubes.

Conventional or Plate-coupled Multivibrator

This basic free-running multivibrator circuit is a simple two-stage resistance-capacitance-coupled amplifier with the output of the second stage coupled through a capacitor to the grid of the first tube (Figure 5-59). Since the signal applied to the grid of a resistance-capacitance-coupled amplifier is reversed in phase in the output, the output of the second stage is in phase with the input to the first, as each stage reverses the polarity of its input. Because the output of the second stage is of the proper polarity to reinforce the signal applied to the first tube, oscillations can take place.

Synchronization of Multivibrators by Pulses

Although multivibrators can be synchronized with a sine-wave voltage, more satisfactory synchronization may be obtained by the use of short trigger pulses. These pulses may be either positive or negative.

A positive trigger pulse applied to a conducting tube of a multivibrator has no effect on the action of the multivibrator. A positive trigger pulse applied to a nonconducting tube in a multivibrator can cause switching action to take place only if the pulse is large enough to raise the grid above the cutoff voltage.

Applications of Multivibrators

The output of a multivibrator may be used as a source of square waves, as an electronic switch, and as a means of obtaining frequency division. It often is used to introduce a time delay between the operation of two circuits by using the leading edge of the square-wave output to trigger one circuit and the trailing edge to trigger the second. Thus, time can be controlled by varying the R-C constants of the multivibrator circuit. In radar, the action of the multivibrator itself is usually accurately timed by triggering it with the output of a master oscillator circuit. As an electronic switch, the output of one tube allows one circuit to operate while the second is cut off by the output of the second multivibrator tube. When the multivibrator switches, the two external circuits are also switched. In radar, the chief use of multivibrators as electronic switches is to produce gate voltages which permit some component part of the circuit to operate only during an accurately controlled interval.

Shock-excited Oscillator

A vacuum tube may be used as a switch to

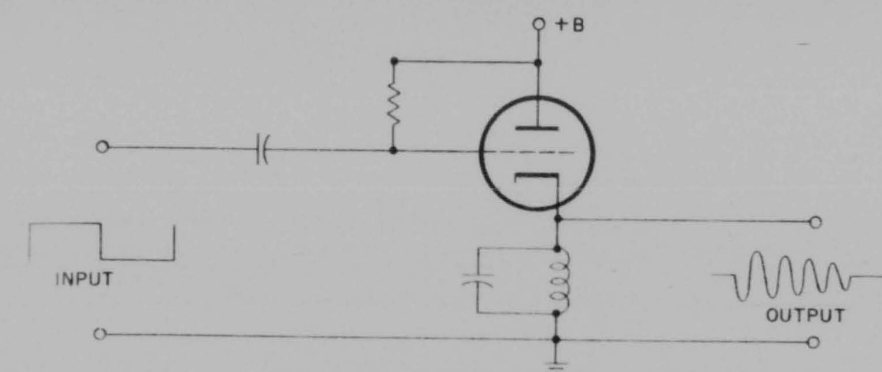

Figure 5–60. Shock-Excited Oscillator.

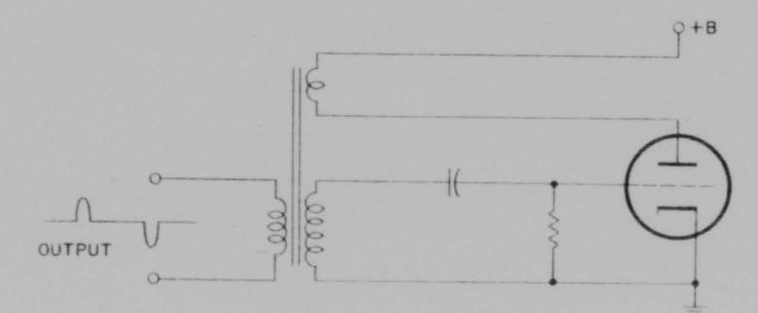

Figure 5–61. Self-Pulsing Blocking Oscillator.

interrupt the steady flow of plate current through a resonant L-C tank circuit as a means of exciting oscillations in the tank. Such a circuit is known as a "shock-excited oscillator" (Figure 5-60) and finds practical applications in instances where oscillations of a certain frequency occurring over short intervals of time are required periodically. It is sometimes referred to as a "ringing oscillator."

Blocking Oscillator

A blocking oscillator (Figure 5-61) is any oscillator which cuts itself off after one or more cycles on account of the accumulation of a negative charge on the grid capacitor. Thus, in an oscillator in which the grid swings positive with respect to the cathode, electrons are attracted to the grid and accumulate on the plate of the grid capacitor nearest the grid. Since these electrons cannot return to the cathode through the tube, they must return through the grid-to-cathode resistor. If the resistor is sufficiently large, electrons may accumulate on the capacitor faster than the resistor permits them to return to the cathode. In this case, a negative charge is built up at the grid which may bias the tube beyond cutoff. After the tube is cut off, it provides no additional electrons to the grid capacitor. However, the capacitor continues to discharge through the resistor, and a point is reached eventually where the tube again conducts. Thus the process repeats and the tube becomes an intermittent oscillator. **The rate of the recurrence of operating conditions is determined by the R-C time constant of the grid circuit.**

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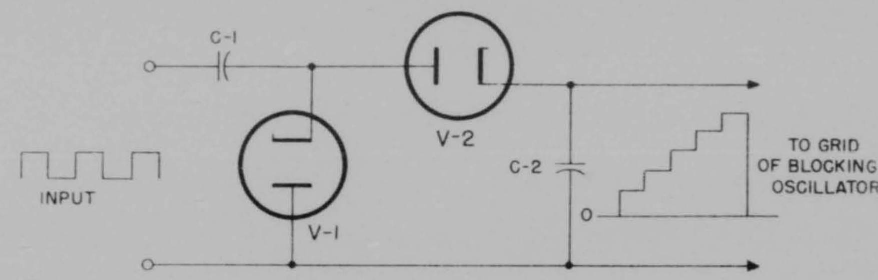

Figure 5-62. Step-by-Step Counter.

Counting Circuits

A counting circuit, also known as a "frequency divider," is one which receives uniform pulses, representing units to be counted, and produces a voltage proportional to their frequency. By slight modifications, the counting circuit is used in conjunction with a blocking oscillator to produce a trigger pulse which is a submultiple of the frequency of the pulses applied.

The pulses applied to the counting circuit must be of the same amplitude and time duration if accurate frequency division is to be made. Thus, counting circuits are ordinarily preceded by shaping and limiting circuits to insure this uniformity by amplitude and width. Under these circumstances, the pulse-repetition frequency constitutes the only variable, and frequency variations may be measured.

Step-by-step Counting

The charge on this capacitor, C_2 of Figure 5-62, is increased slightly during the time of each positive pulse, producing a step voltage across the output. These steps decrease in size exponentially as the voltage across C_2 approaches the final value, the rate being dependent upon the output impedance of the driving circuit. As long as there is no path through which C_2 can discharge, the voltage across it continues to increase with each successive pulse until it is equal to the amplitude of the applied signals. At this point, the cathode of V_2 is held at a positive voltage equal to that on the plate during the pulse time and the tube fails to conduct.

In order to use the step-by-step counter as a frequency divider, a sensitive circuit, such as a single-swing blocking oscillator, is connected to the output terminals (Figure 28). The blocking oscillator V_3 is triggered into operation when the voltage across C_2 reaches a point sufficiently positive to raise the grid of V_3 to cutoff. The regenerative action of the blocking oscillator is such that, once conduction starts, the grid swings positive with respect to the cathode and grid current quickly discharges capacitor C_2 back to ground potential. Any attempt for C_2 to charge to a negative voltage is prevented by the clamping action of V_2 and V_1.

5. FUNDAMENTALS OF A RADAR SYSTEM

Detection by Radio Echoes

Basically, a radar set includes a radio transmitter, a receiver at the same location, and an indicator to show the presence of echoes and thus of objects, as shown in Figure 5-63. The transmitter has a directional radiating system from which electromagnetic waves are propagated with the velocity of light until they strike a distant object or objects and are scattered or reflected thereby. Some of the scattered or reflected energy is returned to the radar station, where it is received. The received signals are then employed in the equipment to determine the position of the object that reflected some of the transmitted energy.

A very great amount of power must be radiated, because an almost infinitesimally

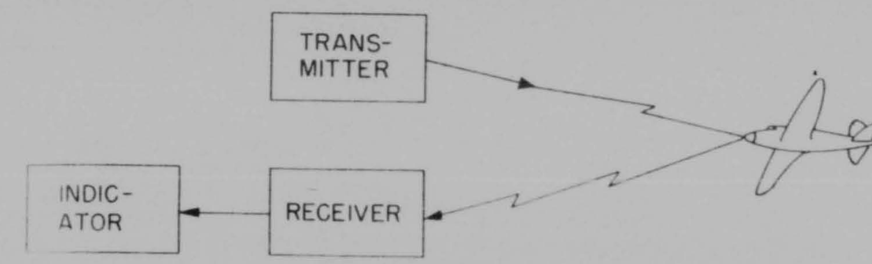

Figure 5-63. Elementary System for Radio Echo Detection.

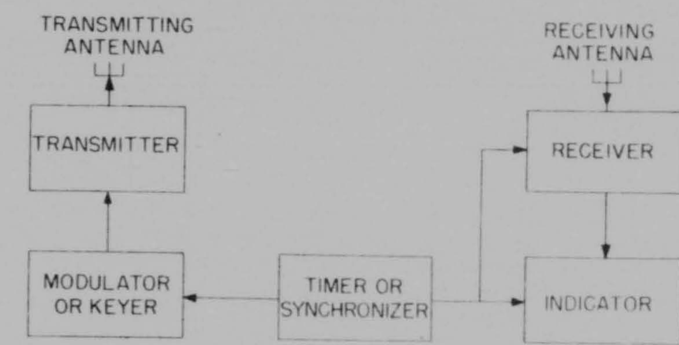

Figure 5-64. Pulse Radar System Using Two Antennas.

small portion of it returns to the receiver on account of the distance traversed and the small reflecting power of a target. Moreover, since the powerful transmitter is operated adjacent to the highly sensitive receiver, which must be able to detect this minute quantity of reflected power, some means must be provided whereby the power radiated by the transmitter may be excluded from the receiver.

Pulse Systems

Most radar equipment is based upon the transmission and reception of pulses of electromagnetic energy of very short duration. The pulse-echo process is repeated periodically at a rate so rapid that a steady image is obtained in a cathode-ray tube. The time interval between the transmission of the pulse and the reception of the echo is proportional to the range of the object. In order to determine the direction of the object as well as its range, the radiation of energy is made highly directive so that any desired region of space may be explored by controlling the direction of the beam.

The basic elements of a typical pulse system are represented in block-diagram form in Figure 5-64. A train of radio-frequency pulses is generated by the transmitter under the immediate control of the modulator, or keyer, and is radiated by the transmitting antenna. The echo pulse is picked up by the receiving antenna, is amplified and detected by the receiver, and is passed on to the indicator, which is usually a cathode-ray tube, where the range and direction of the reflecting object are displayed. The timer serves to synchronize various functions of the transmitter, receiver, and indicator.

Antennas

The transmitting antenna is at least moderately directive in most applications and is often highly directive. It is usually con-

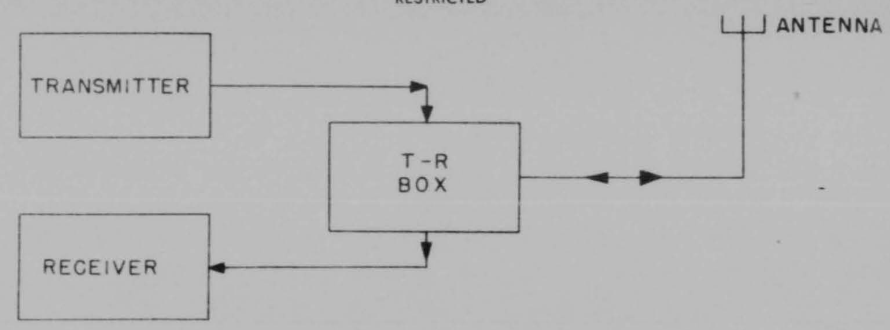

Figure 5—65. Single-Antenna Radar System.

structed to permit orientation in any desired direction. In order to obtain the required directivity and at the same time to limit the size of the antenna to meet space and weight requirements, the radio frequency employed must be very high, being seldom below 100 megacycles or higher frequencies (shorter wavelengths) and greater directivities. Waves shorter than 50 cm. are usually called microwaves. Microwave systems now in use employ frequencies of about 3,000 Mc/s (10 cm.), or 10,000 Mc/s (3 cm.). At lower frequencies—of the order of hundred of megacycles per second—the antenna system comprises a multiple array of linear elements, but at the higher frequencies, parabolic reflectors and other special devices are used almost exclusively.

The receiving antenna is similar to the transmitting antenna, and, in many sets, the same antenna is used for both transmitting and receiving. The use of one antenna instead of two saves space and weight and obviates the mechanical difficulty of making two highly directive antennas point in exactly the same direction. When only one antenna system is used, some kind of switching means is required to connect the transmitter to the antenna when a pulse is to be radiated, and then to connect the receiver with the antenna during the interval between pulses. This device, indicated in Figure 5-65, is generally called a "T-R (transmit-receive) box." It usually comprises a spark-gap tube and associated resonant system in which a spark is produced when a pulse is transmitted. The spark reduces the portion of the transmitter power reaching the receiver.

Transmitters

Successful power amplifiers for very high frequencies are almost nonexistent; consequently, radar transmitters invariably use a simple oscillator that is directly coupled to the transmitting antenna system. In microwave transmitters, the oscillator is usually a magnetron; for longer waves, it is usually a group of vacuum tube triodes.

Modulators

The modulator is a controlled source of anode power for the oscillator. The modulator can be thought of as a "keyer," and it is frequently referred to by this name since it supplies power to the transmitter only during the pulse period. In order to control the modulator so that it supplies plate power to the transmitter in pulses of the desired duration and repetition rate, a combination of circuits called the "timer" or "synchronizer" is employed which supplies signals for actuating the keyer at precisely regular intervals.

Radar Receivers

Radar receivers are usually of the superheterodyne type and must be capable of accepting signals lying in a frequency band considerably broader than the bands encountered in conventional communication practice. Bandwidths of from one to ten megacycles per second may be encountered in radar receivers.

Indicators

The output signals from the receiver, to-

gether with data representing the orientation of the antenna, provide the available information as to the position of the reflecting object. An indication of this information, suited to the particular operational characteristics of the equipment, must be made. Apparatus for performing this function is called the "indicator;" generally it comprises a combination of circuits and cathode-ray tubes. Such tubes can present vastly more information than can a simple pointer-type meter; nevertheless, certain special applications employ meters or other electromechanical devices.

Types of Presentation

There are many types of indication and many different ways in which the direction of the antenna beam may be varied with time. Each combination has its particular field of application in radar work. Three especially important types of presentation are denoted as Type A, Type B, and Type P. Type P presentation is also called **"plan position indication"** (abbreviated PPI).

Type A Indication

Type A presentation employs a cathode-ray tube for presenting data primarily on the range of a reflecting object. The scanning spot is maintained at constant intensity, and is set in uniform motion horizontally across the face of the cathode-ray tube at the instant at which a pulse of energy is radiated by the transmitter. The spot starts at a point near the left-hand side of the fluorescent screen and moves to the right across the tube at constant speed.

Received signals cause vertical deflections of the scanning spot roughly proportional to the signal strength. Upon reaching the right end of the screen, the spot is extinguished by grid control in the tube and is returned to the left end, where it is illuminated again to retrace the same path on the next succeeding transmitted pulse. The persistence of the screen of the tube reduces flickering of the image on the screen. The appearance of the fluorescent screen, when, for example, echoes from two separate targets at different ranges are received is that shown in Figure 5-66A. A vertical deflection corresponding to the

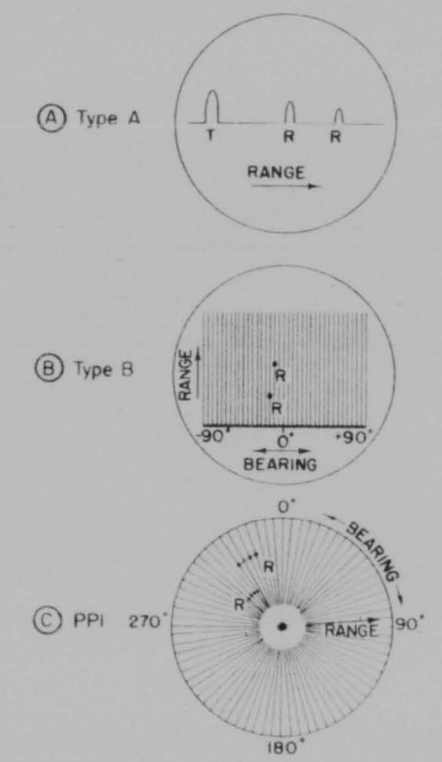

Figure 5—66. Types of Indication.

transmitted pulse appears at the beginning of the scanning line, and others—in the form of smaller replicas of the original pulse—appear at positions on the trace that depend on the range to each reflecting object. The vertically presented pulse outline is dubbed a "pip," in radar parlance.

The horizontal distances across the screen from the end of the transmitted pulse to the ends of the several received pulses constitute indications of the distances to the respective reflecting objects. A rough indication of the direction of an object may be obtained by rotating the antenna beam to that position which gives maximum pip height. A large number of targets may be shown at the same

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time on a Type A indicator, and a series of objects lying in a straight line from the radar station may be resolved on the screen and have their respective ranges indicated.

Type B Indication

In Type B presentation, the azimuth (bearing) and the range of reflecting objects are presented on the screen of the tube as absciasa and ordinate, respectively. In radar sets having this presentation, a highly directive antenna system is rotated about a vertical axis so that the radiated beam covers a horizontal plane. The potential spot which would appear if the grid control were to turn it on, is given a horizontal motion synchronously with the rotation of the antenna, corresponding to at least a portion of the angle of rotation of the antenna system. Thus, in the absence of other deflection, the scanning spot would describe a horizontal line across the lower portion of the indicator screen.

A uniform vertical motion from bottom to top of the screen is also imparted to the scanning spot, each vertical line being synchronized with a transmitted pulse for the indication of range. The repetitive vertical sweep is very much more rapid than the horizontal sweep. In Type B presentation, the spot is maintained at very low intensity, and the received signal is impressed upon the grid of the cathode-ray tube to intensify the spot and to cause a bright area to appear on the screen at a point representing the azimuth and range of the target. The transmitted pulses are represented by a bright horizontal line at the bottom, called the "base line" of the pattern. The appearance of the indicator screen is shown in Figure 5-66B.

The frequency with which pulses are transmitted is important in relation to the width of the radiated beam and the speed of rotation of the antenna in determining the angular coverage and resolution of the system. The pulse repetition rate should be so chosen that pulses are transmitted at sufficiently small angular intervals to insure that targets within range are not missed simply because no power is radiated toward them. In some equipment, the pulse repetition rate is relatively high, and the vertical range-sweep lines are correspondingly closely spaced on the screen.

PPI Indication

Type P presentation is employed where the tactical conditions require that range and bearing information—but not elevation information—be obtained concerning objects in or near a horizontal plane centered at the site of the radar station. The PPI screen, which is illustrated in Figure 5-66C, provides information on range and bearing, plotted in polar co-ordinates. In a set employing plan position indication, the antenna is rotated uniformly about a vertical axis so that the principal axis of the radiated beam periodically searches all angles in a horizontal plane. The beam is usually narrow in azimuth and broad in elevation. A very large number of pulses are transmitted for each revolution of the antenna.

As each pulse starts, the unintensified spot starts to move outward with uniform speed along a radial line from the center of the screen to provide a radial range indication. After reaching the edge of the tube, it returns quickly to the center to begin another radial trace when the next pulse is transmitted. Normally, the cathode-ray tube is biased so that the scanning spot is at the threshold of visibility, but when an echo is received, the spot is intensified to make it visible.

The polar angle of the radial line on which the spot appears indicates the azimuth of the antenna beam and hence of the reflecting object. The radial distance of the spot from the center of the tube indicates the range of the object. In this way, what is essentially a map of the territory surrounding the observing station is produced on the indicator tube.

Radar Receivers

A distant target reflects back to the receiving antenna in a radar system a very small fraction of the transmitted energy—less, perhaps, than one-billionth of a billionth part. The echoes return as pulses of high-frequency energy of the same nature as those sent out by the transmitter, except that the power during a pulse may be measured in

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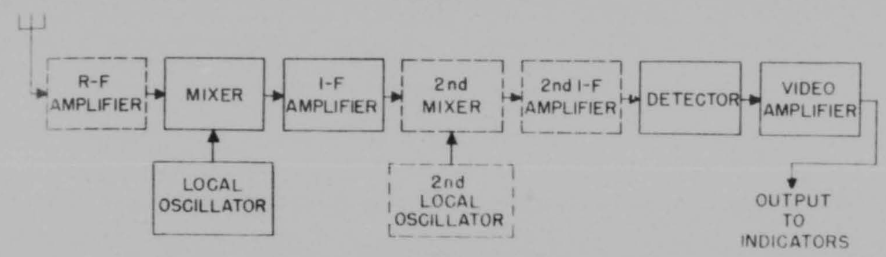

Figure 5—67. Block Diagram of a Radar Receiver.

fractions of micromicrowatts instead of in kilowatts, and the voltage at the antenna is in the range of microvolts instead of kilovolts.

Information about the position of the target is presented to the eye when the reception of an echo causes the movement or appearance of a spot of light on a cathode-ray tube, which requires for its operation a voltage of the order of 20 volts at least, and which will not respond to the high frequencies within a pulse. An amplifier and detector must therefore be used which are capable of producing a visible indication on the cathode-ray tube when connected to an antenna giving pulses of extremely high-frequency voltage whose amplitude is measured in microvolts and which last, at the most, a few microseconds. This very special amplifier and detector is the radar receiver.

The most suitable arrangement of the receiver components to meet the requirement outlined has been found to be that shown in the block diagram in Figure 5-67. This is a superheterodyne receiver, which utilizes amplification at a frequency intermediate to the frequencies of the input and output circuits.

An r-f amplifier of one or two stages is usually found in receivers operating in systems at or below 1,000 Mc/s. Above this frequency, the incoming signal is converted directly to the intermediate frequency without amplification at the input frequency. The principal factor in determining what the first few stages shall be is the amount of noise which they produce in the receiver output. Noise introduced in the first stage or two, where the signal is weakest, will be amplified by the full gain of the receiver, and, therefore, will be the most important noise in determining the signal-to-noise ratio in the output.

After conversion to the intermediate frequency, the signal is amplified in several stages. Most of the gain of the receiver is obtained in the i-f amplifier, and the overall bandwidth of the receiver is often determined in large part by that of the i-f stages. To reduce feedback, a few receivers use a second mixer to convert the signals to a second intermediate frequency for further amplification, since feedback between stages operating at different frequencies is negligible.

Detection of the signal is followed by amplification in one or more stages at the video frequency. The output stage is usually a cathode follower, which provides a low-impedance source for supplying the video pulses through a cable to the indicator.

Various modifications in the type of coupling between stages, type of mixer, detector, and local oscillator, and number of stages of amplification at the different frequencies, are found in different receivers, depending in large part upon the carrier frequency of the radar system. However, the receiver is always designed with as little noise as possible and with sufficient gain so that noise, rather than lack of gain, limits the smallest visible signal.

In the superheterodyne, the incoming signal is applied to a mixer consisting of a nonlinear impedance such as an over-biased vacuum tube or a diode. The signal is mixed with a steady signal generated locally in an oscillator stage, with the result that a signal bearing all the modulation applied to the original signal **but of a frequency equal to the differ-**

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ence between the local oscillator and incoming signal frequencies appears in the mixer output circuit. The output from the mixer stage is fed into a fixed tuned intermediate-frequency amplifier, where it is amplified and detected in the usual manner and passed on to the video amplifier.

The advantages of superheterodyne reception are directly attributable to the use of the fixed-tuned intermediate-frequency (i-f) amplifier. Since all signals are converted to the intermediate frequency, this section of the receiver may be designed for optimum selectivity and amplification. High amplification is easily obtained in the intermediate-frequency amplifier, since it operates at a relatively low frequency, where conventional pentode-type tubes give a great deal of voltage gain.

SECTION IV—SYNCHROS AND SERVOMECHANISMS

1. INTRODUCTION

Often in fire control and radar equipment, an arbitrary motion imparted to one shaft must be reproduced accurately by the motion of a second shaft, sometimes with torque amplification. A direct mechanical connection between the input or control shaft and the output or load shaft may not be feasible because of their separation distance or because of the need for torque amplification. When torque amplification is not required, extensive use is made of electrical data-transmission or remote-indication systems. The device most commonly used for remote indication are synchros, which resemble small electric motors and operate on single-phase alternating current. When torque amplification is required, use is made of electrical or hydraulic devices called servomechanisms. Servomechanisms commonly include synchro units when control from a remote point is required.

2. GENERAL

Radar sets use remote-control systems to turn the antennas, to drive dials which indicate the antenna position, and to synchronize the PPI (plan position indicator) deflection coil with the antenna. The antenna and the PPI coil of shipborne and airborne radar sets may be controlled either in true bearing or in relative bearing. In fire-control work, one group of remote control mechanisms transmits data on range, bearing (azimuth or train), and elevation of the target to a computer. A computer is a machine which calculates the proper aiming of the gun to place a projectile on the future position of the target, with allowances for the relative motion of the target, and for gravity, wind, and other ballistic effects on the projectile. A second group of servomechanisms transmits to the gun the computed bearing and elevation of the gun, and sometimes the range of the target. The gun may be aimed either automatically by servomechanisms or manually by operators who match pointers with pointers driven by remote-indication mechanisms.

Synchros and servomechanisms find many other uses, especially on ships and on aircraft. For example, synchros are used as compass repeaters, and for indicating the positions of wing flaps, rudders, and landing gear. Servomechanisms are used for pointing searchlights, for remote control of landing gear, and for manual and automatic steering.

3. SYNCHROS

A synchro is a small alternating-current machine used for the transmission of angular-position data. Synchros are known also as "synchronous" units or "selsynchronous" units, and by various trade names such as Selsyns, Synchrotie, Autosyn.

A special example of the use of synchros is the system for turning a PPI deflection coil in accordance with the rotation of the radar antenna. The antenna is connected by gears to the shaft of the synchro generator. Voltages from the generator are transmitted to the PPI synchro motor and cause the motor

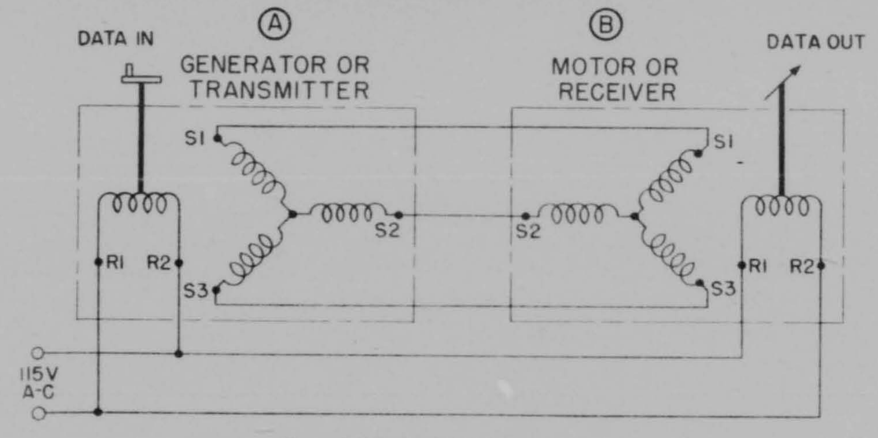

Figure 5–68. Typical Selsyn System.

to turn in correspondence with the generator motion; therefore, the deflection coil geared to the motor is made to follow the antenna motion, and the direction of the range trace on the indicator tube corresponds with the direction of radiation from the antenna. For greater accuracy, the synchros are usually geared to turn faster than the antenna and coils.

The synchro generator is often called a transmitter, and the motor, a receiver, or follow-up. The generator and motor are identical in construction except that the motor is equipped with a mechanical, oscillation damper and with low-friction ball bearings, whereas the generator does not have the damper and usually does not have ball bearings. Each machine has a stator (stationary part) and a rotor (rotating part), built of sheet steel laminations and wound with coils of wire.

The rotor has two salient (projecting) poles and one winding. Connection to the winding is made through brushes resting on two slip rings.

The electrical construction of both receiving and transmitting Selsyns is identical. The rotors are single-phased and fed from the common power source such as the 60 cycle line supply. The stators of both the transmitting and receiving Selsyns are three-phase with the corresponding legs of the transmitting and receiving Selsyns connected together. (Figure 5-68).

The transmitter Selsyn (A) is frequently called a "Selsyn generator," and the receiver Selsyn (B), a "Selsyn motor." Electrically, the Selsyn generator and the Selsyn motor are identical. The physical difference mentioned above is in the damper which consists of a lead ring within friction plates on a sleeve which is secured to the rotor shaft. The lead ring has a large amount of inertia and can be rotated on the sleeve only with considerable difficulty. Any violent oscillation of the rotor rotates the sleeve. The lead ring cannot follow this motion immediately because of its inertia, so that a large damping effect is produced on the oscillating motor, which quickly stops the movement. It should be noted that a Selsyn generator does not necessarily rotate continuously as do most electrical generators, but, may change its position by a few degrees. As the rotator of (A) is turned to a specific position with respect to the stator, voltages are induced in the stator's windings. These voltages cause current to flow in the identically connected stator windings of the receiver Selsyn. These currents set up a field in the receiving Selsyn which will cause the receiving rotor's Selsyn to assume a position where its field will generate a voltage in the receiver's stator's windings. This will exactly cancel those generated in the transmitter stator's winding. There is one and only one

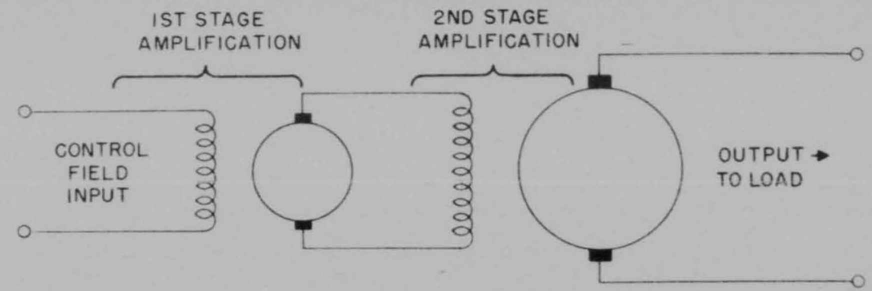

Figure 5—69. Electromechanical Amplifier.

position of the "data out" rotor, whereby this system is in electrical equilibrium as just described. Any angular displacement of the "data in" rotor will be exactly and instantly reflected by the "data out" rotor to keep this system in equilibrium. If the "data out" rotor should become restrained, heavy electrical stresses and currents would be set up in both the generator and receiver stator windings.

Another interesting and useful phenomena of the Selsyn system is that if the power connections, R_1 and R_2 of the "data out" Selsyn rotor, were removed and a common-voltage measuring device such as a voltmeter were placed across these two terminals, then any angular displacement would be shown as a voltage having its phase relations to the line voltage as a function of the angular displacement. This voltage is known as an "error-voltage" and is very useful in many positioning devices.

4. SERVOMECHANISMS

It can be seen that if the Selsyn system is connected normally, that is with both rotors connected to the 115-volt 60-cycle power source, that accurate data will be transferred from the transmitter to the receiver. However, if any load is placed upon the receiver, it will be necessary to generate a voltage and current in the receiving Selsyns to furnish the power for carrying this load. Therefore, a new device has to be considered if the receiving system is to have a load such as a radar antenna, control mechanism for anti-aircraft guns, etc.

Any system which will take this received data and enable it to carry a heavy mechanical load is known as a "servo system" or "servo-mechanism." A simple servo system can be constructed as follows: (Figure 5-69.) The "data out" Selsyn rotor is fixed and the power connections to its rotor windings disconnected. The error-voltage explained above is matched against the line-voltage supplied to the "data in" rotor windings. These voltages are matched by a vacuum tube circuit both for phase relation and magnitude. For example, if the error-voltage is leading the line-voltage, a positive DC voltage is turned out by this electronic device. If it is lagging, a negative voltage will be turned out by the electronic device. Thus it can be seen that any angular turning of the "data in" Selsyn would be reflected by a positive or negative voltage depending on the direction of the displacement of "data in" rotor from the "data out" rotor. This DC voltage may be turned into a high torque rotary motion by the use of two generators and a motor. (Figure 5-69.) The small DC voltage from the electronic device may be fed to the field of a small electrical generator. The output from this generator may be fed to the field of a larger generator, the output of this larger generator may then be fed to a turning motor. The polarity of the final output will be in direct relation to the polarity of the input to the first generator. Thus, the polarity of the output of the electronic device which has matched the error-voltage to the line-voltage determines the direction of rotation of the final motor. In this manner, a hand wheel connected to a small Selsyn motor in a building several hundred feet from a radar antenna may activate and control the rotating of this antenna through electrical linkage.

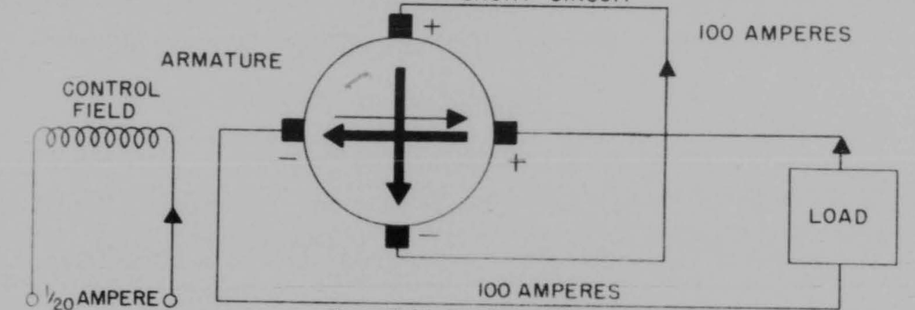

Figure 5—70. Simple Amplidyne.

There is a device which eliminates the use of this complicated series of motors and generators to take care of this load. It is called an "amplidyne". The amplidyne consists of one drive motor and one generator. The small control field is fed to the generator in the usual manner. The output caused by this small control field is then short-circuited causing a very heavy current. (Figure 5-70.) The large magnetic field associated with this heavy current then supplies the field for other windings in the same generator. This heavy field, controlled by the light field, controls the output to a heavy load.

Often there is a requirement for a servo system that does not have to carry a heavy load such as the light, fast-moving servo systems in antiaircraft gun-laying computers and airborne gun-laying computers. These servo systems usually consist of the error-voltage from a Selsyn system being fed to a light two-phased motor. The phase comparison and the magnitude of the error-voltage determines which way the light motors turn.

5. COMPUTERS

Computers are electromechanical devices in which voltages are made to represent distances and other data. For example, one voltage equals two hundred yards. Height of an aircraft, distance north, or distance east from a certain point, can be represented by these voltages. As the aircraft moves, the voltage representing these distances will be fed to a resistance capacity network, which will put out a voltage in proportion to the rate of change of the applied voltage. This is known as a "differentiating network." This differentiated voltage will represent speed giving a basis for calculating future points of aircrafts or other targets based on their rate of travel. Servo systems can then rotate specially wound potentiometers whose voltages vary in proportion to sine-cosine ballistic curves charts of the atmospheric effect on trajectory and parallax.

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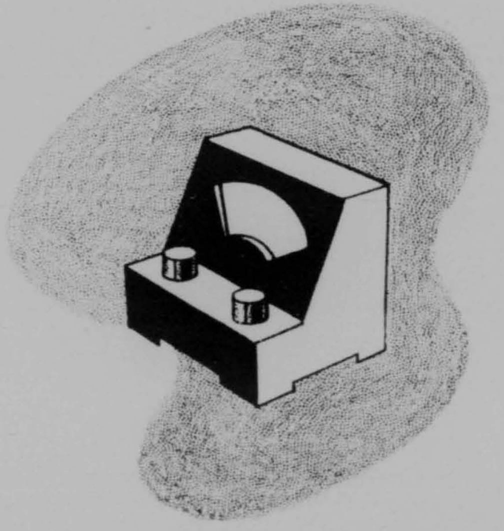
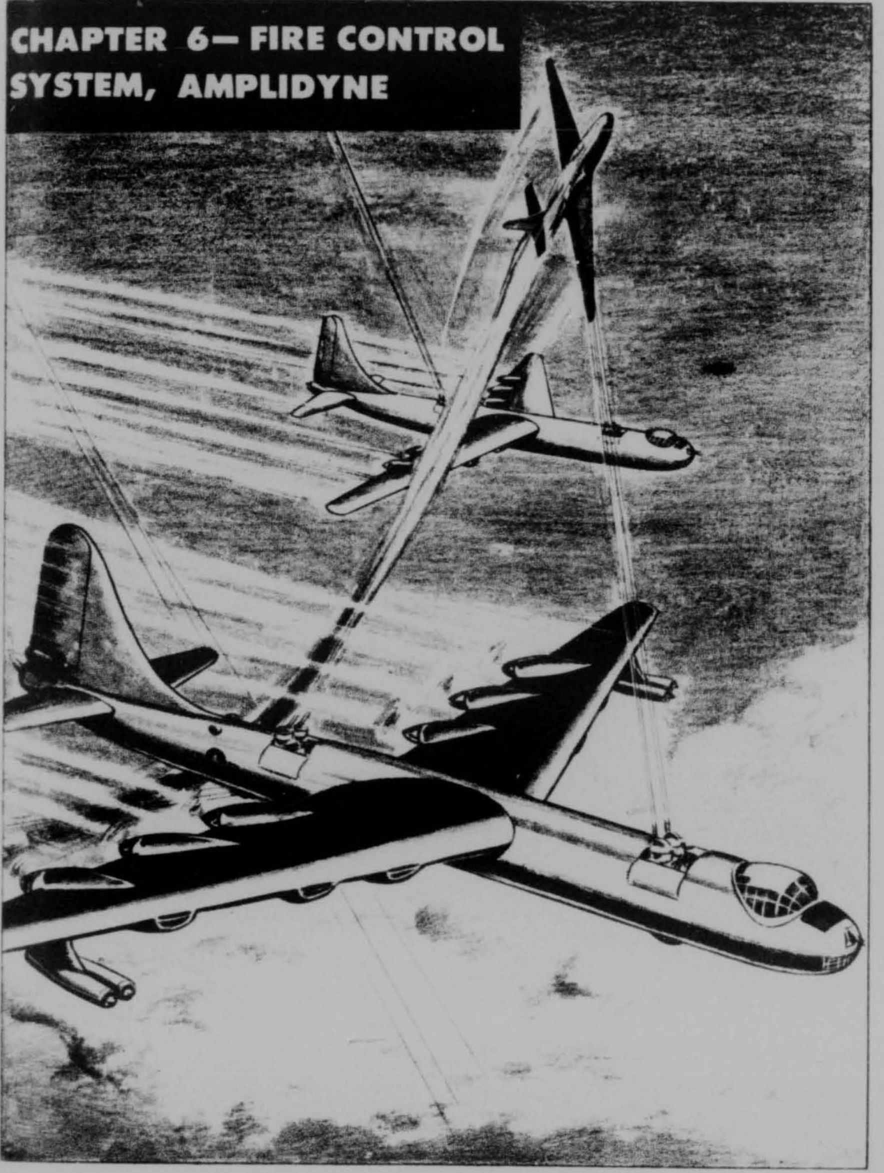


CHAPTER 6— FIRE CONTROL SYSTEM, AMPLIDYNE



SECTION I—THE B-29 AND B-50 FIRE CONTROL SYSTEMS

1. INTRODUCTION

The application of armament to aircraft in combat had its origin in the first World War, when enemy flyers on observation missions were actually known to have thrown rocks at one another. Such meager and inaccurate armament gradually developed into the fixed and flexible cal. .30 machine guns which typify air movies of World War I.

This type of armament, with the pilot having two fixed forward guns and the observer having twin guns on a flexible scarf-and-ring mounting, was in use up until the last few years. Then as larger cal. .50 guns were adopted to give greater fire power and increased range, it became no longer practical for the gunner to try to maneuver the guns by hand, due to increased recoil and to the much greater wind loads developed by high speeds of modern aircraft.

2. ADVENT OF POWER-DRIVEN TURRETS

To overcome flinching of the gunners, to combat wind loads as high as 350 foot-pounds for two guns, to give increased accuracy, and to permit locating guns outside a pressure-sealed cabin, a new prime-mover was required for the guns now mounted in a turret. The earliest powering of turrets was done by the British, who developed well-engineered and accurate hydraulically-moved turrets, locally operated by gunners sitting and sighting in the turrets. These hydraulic turrets were successfully used in the Boulton-Paul "Defiant", two-place night fighter, and in such bombers as the Vickers-Armstrong "Wellington"

The first known German power turret made a belated debut, probably because of production difficulties rather than problems of design. The German policy military aviation has traditionally been one of standardization and concentration on easily produced planes, and, having early frozen their designs on non-power-driven turrets, they had been slower than expected in the utilization of this type of armament.

3. ELECTRICALLY-DRIVEN TURRETS—GENERAL

The armament applications with which this chapter is concerned are primarily defensive installations, on bombers and heavy aircraft. On these, flexible gun turrets counteract the fighter plane's advantage of speed and maneuverability. The fighter is usually a one-place plane, very fast and maneuverable, with a large array of machine guns and cameras, all fixed, pointed forward and fixed by the pilot. Several multiplace fighters, both for day and night work, have been produced. These "destroyers of the air" are heavily armed, sometimes having numerous fixed guns for the pilot as well as a remote turret which is used both offensively and defensively. An example is the Northrop P-61, a night fighter, which carries a single upper four-gun turret controlled primarily by a nose gunner for offensive use, but also controllable from an aft sighting station by a rear gunner.

4. FACTORS AFFECTING APPLICATION

The two most important factors influencing aircraft armament installations are (1) fire coverage and (2) fire power. The satisfactory solution of these two problems is imperative, as they determine more than anything else how long the aircraft will stay aloft in combat.

Fire Coverage

Every effort is made to eliminate "blind spots"—vulnerable directions from which an aircraft's guns can not shoot—because enemy pilots are surprisingly quick to discover these

areas and capitalize upon them in battle. Our early Flying Fortresses, the B-17-C's, for example, had no tail guns. The Germans and Japanese quickly found that the plane was defenseless against attack straight from the rear, and a large number were shot down because of that situation. The later model B-17's had tail gunners, and many had fine shooting until the enemy learned of the change of design. Some blind spots, such as those caused by the rudder and elevators of an aircraft, are very hard to cover. The use of a tail turret eliminates this blind area.

Fire Power

Fire power determines the amount of destruction of which the military aircraft will be capable to perform. The modern tendency, successfully advocated by the British, is to crowd as many guns as possible into the plane, and to throw as much weight of projectiles as possible into the enemy, relying on blasting him to pieces rather than hitting a few vital spots.

The guns on some British planes are now throwing over 200 pounds of projectiles a minute, and engineers are talking of rates as high as 1200 pounds per minute in the future. These high rates of fire are particularly desirable for night fighting which provides such a short time for sighting and firing.

There is, of course, a weight limit on the number of guns and the amount of ammunition a plane can carry without cutting down its bomb load, range and maneuverability. A plane must not be so heavily armed that its aerodynamic efficiency is seriously hampered and, at the same time, it must be able to defend itself successfully in the air. This balance of armament versus weight is usually the problem of the aeronautical engineer and the Air Force, but it also is a problem which affects armament products.

To achieve increased fire power without excessive increase in weight, the Air Force has utilized what is probably the best aircraft machine in the world—the cal. .50 Browning machine gun.

Still larger guns are used, such as the 37-mm (1.45" bore) cannon. The shells for this gun are so heavy that few can be carried, and the rate of fire is considerably less than the cal. .50 machine gun. Thus the "spray effect" of a machine gun is lost, and it becomes a single shot proposition, requiring accuracy and a computing sight. However, hits from this gun are highly effective against heavily armored planes, tanks, and ground fortifications.

5. PROBLEMS INVOLVED

Maneuverability

Increased number of guns per turret and larger weapons have been a prominent motivating factor in the development of the power-driven enclosed gun position. Among the early considerations for these turrets was the type of motive power which had to be accurate as well as sensitive, require little effort to operate, possesses reserve power, and be comparatively light in weight. Furthermore, it had to be capable of smooth and instantaneous variable speed from one direction of rotation to full speed in the other direction. In addition to rotation of the turret, controls had to be provided which would adjust the turret or gun mount in a vertical direction, simultaneously with an independent or horizontal motion.

Gunsights

Besides the problem of providing power to move a turret and gun mount in several directions, the designers have had to consider the problem of close installation. Since the only available and practical gunsights were mounted directly on the guns or in the line with them, the gunner required a seat which would move in coordination with the guns, enable him to keep his eye continually on the sight, allow him to maintain full control under all flying maneuvers.

Sizes

In the earliest powered turrets, installed on smaller airplanes, great difficulties were experienced because of the lack of space in the fuselage, causing serious restrictions to be placed on the turret dimensions. The gunner had his parachute packed in the seat, oxygen flasks, radio equipment, camera, interphone communication, life preserver, gun and clothing heaters, flares, all in addition to the gun mount, the guns and spare ammunition boxes. Modern turrets further require the guns be fed, not from magazines, but from continuous belts, these belts hanging from the guns, and even with the best of design they clutter up the turret. These requirements, and others, have already been met in several designs of British and American turrets.

Cutouts

One important consideration which has to be met by all turret designs for amidships positions is an efficient fire cutout or gun restrictor, which automatically stops the guns from firing when the field of fire is across the control surfaces, radio masts, or sections of the fuselage. This is done both mechanically and electrically. One cutout mechanism also incorporates a compensator for rotational speeds, which assures a minimum of cutout cover for slow operational speeds, the cutout cover being automatically increased as the speed of rotation increases.

6. PROBLEMS AFFECTING TURRET DESIGN

Tailoring Armament to Aircraft

As both fire-coverage and fire-power problems are usually decided by the USAF in cooperation with airplane designers, most of the armament manufacturer's work is concerned with tailoring armament into airplanes which are designed. The armament is built into the plane, rather than the plane being built around the armament.

Space Limitations

Aircraft, space limitations are critical, particularly on light and medium bombers, consequently the General Electric turret equipment, which is used extensively, is quite compact. The limiting feature of the horizontal diameter is the sweep of the gun butt, about which very little can be done.

Weight

Another important consideration is that of weight and its distribution. Added weight not only reduces range and maneuverability but also affects the initial position of the airplane's center of gravity which, in turn, affects the ship's handling characteristics. Aircraft companies are greatly concerned with any added weight because their planes must meet specified performance requirements, and the more weight, the more difficult is the job.

Structural Strength

Structural strength in the neighborhood of the gun emplacement must be sufficient to stand the recoil forces and the wind loads caused by addition of the guns. The average recoil force of the cal. .50 machine gun is about 1750 pounds per gun, 3500 pounds for a two-gun turret, and 7000 pounds loading for a four-gun turret, assuming synchronized firing. This is an intermittent impact load which may last for several seconds. For horizontal firing, it is sheer load in the longerons and frames. For up or down firing, it constitutes a compressive load. This great stress must be properly distributed to the bulkheads.

Torques

Wind loads cause torques tending to rotate the guns and produce torsional stresses on the supporting members. It is important, for accuracy of fire, that the structural stiffness be sufficient to hold the guns rigid against this torque, which may be higher than 350 foot pounds for two guns.

Muzzle Blast

The discharge of gases from the gun barrel, known as "muzzle blast", may be very violent and injurious to the thin metal "skin" of the plane near the muzzle. Every General Electric turret installation has required some protection against muzzle blast. This can be obtained by means of a sheet of sponge rubber cemented to the airplane's skin with a sheet of .015" stainless steel over it, a device which has proved to be effective in the prevention of denting and burning of the skin and the tearing up of rivets.

Rigidity

An important factor in the accuracy of a remote-control turret is the rigidity of the aircraft structure between the sight and guns. Twisting motion of the structure due to motion of the rudder, bending loads from the elevators, and roughness of the air, all cause structural weave and lack of correspondence between the sight and the gun. Sometimes a permanent set gets into the structure and spoils an installation alignment. It is best, of course, to have the sight and guns located as near to each other as possible. On some airplanes such as the B-29, however, they will be about forty feet apart.

Protection

Ease of protecting personnel and accessory equipment must be considered. Pilots and other personnel on the plane usually have some armor protection but, as yet most armament equipment has no protection. It would be highly desirable to armor the vital spots of such systems, such as junction boxes and servo-amplifiers, but always the problem of weight must be considered.

Maneuver Loadings

The location of turret equipment is influenced by maneuver loadings, or the tremendous forces of acceleration in places remote from the center of gravity, such as the tail.

7. PRESSURIZATION

Pressurization of planes for high-altitude flying brings in many more complications. It is quite difficult to maintain pressure in an ordinary plane, but when we mount flexible guns on a ship, making holes in its skin, we are faced with exceedingly complex problems of pressurization. The gun stations must be sealed, which is easier to do with a remotely controlled emplacement than with a locally handled turret.

8. EFFECTS OF USE FOR WHICH AIRPLANE IS INTENDED

The intended tactical use of the plane is another important consideration in engineering turret equipment. Air speed affects drag, wind loads, and the range of the computer. Altitude also affects wind loads; causes poor motor commutation; makes the brushes wear rapidly, as much as 1/4 inch an hour due to a dessicating effect; makes lubrication difficult because of the stiffening of any oil in low temperature; reduces the cooling of rotating equipment due to the decreases in weight of air flow; makes the opening of the turrets liable to freezing; and necessitates heating the turret. This heating is necessary to keep the ammunition at its maximum power and is a problem which is not yet known to be solved.

9. PERFORMANCE SPECIFICATIONS FOR TURRETS

The power supply for the turrets must be adequate to provide the necessary turret velocities and accelerations. From British data, the optimum motions are velocities of 45 degrees per second in azimuth and 30 degrees per second in elevation, and accelerations of 90 degrees per second^2 in azimuth and 60 degrees per second^2 in elevation. Turret systems now in use are still retaining approximately the same velocities and accelerations. In addition to these values, the instantaneous peak demands, which occur when the guns are accelerated at their maximum rates from position at right angles to the line of flight at maximum speed of the plane, also depends upon the degree of synchronization required (the rapidity with which the guns must follow the sight).

10. GUN INSTALLATION TYPES

There are several types of armament systems, or gun installations for military aircraft, each with advantages peculiar to itself. These advantages usually determine the selection of a certain type of armament for a particular airplane. The following are the types of armament systems which are used:

Fixed Mounts

The guns are mounted in fixed positions of the airplane. (Figure 6-1.) The pilot maneuvers the plane in order to aim the guns.

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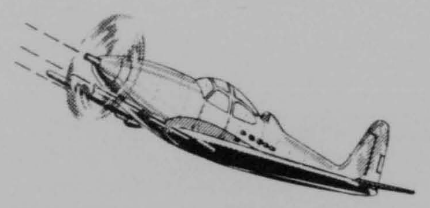

Figure 6—1. Flexible Mount.

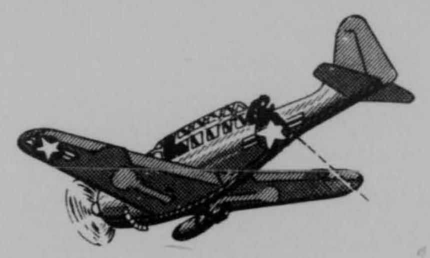

Figure 6—3. Flexible Mount—Power Drive.

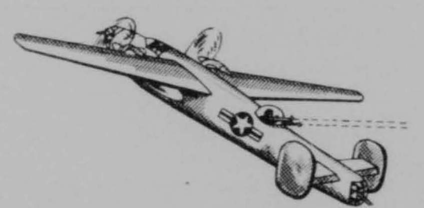

Figure 6—2. Flexible Mount—Manual Drive.

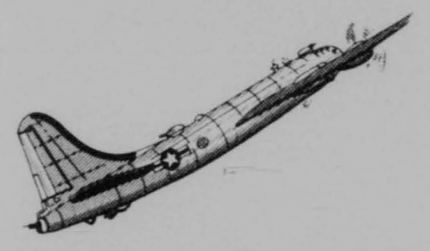

Figure 6—4. Turret Positions.

Flexible Mounts—Manual Drive

The airplane (see figure 6-2) has a flexible mount for the gun. The gunner can move the gun, making it possible for him to aim without maneuvering the airplane into position as in fixed mounts. In this installation, the force required to move the gun is supplied by the gunner himself.

Flexible Mounts—Power Drive

The airplane carries a power-driven gun turret. (Figure 6-3.) The gunner, located in the turret, aims the guns by controlling the electrical or mechanical power which drives the turret.

Central-station Fire-control System

The central-station fire-control system is one in which the gunner is located apart from the gun turret or turrets. In the illustration (Figure 6-4) which is simply to show the principle of a turret located at a point remote from its sight, the gunner's post and the sight are in the forward "blister" above the wings, while the turret which mounts the guns can be seen back toward the tail. The gunner manually aims the sight at the target, and through power control, the guns are also made to point at the same target.

11. ADVANTAGES OF REMOTELY CONTROLLED TURRETS

Position of Gunner

It is this system, central-station fire-control, that is to be discussed. With it, the gunner and his sights can be located at that part of the plane which suits his purpose best, that is, where he has a maximum area of vision, where he can be protected by armor, and where he can be relatively comfortable. This last point is of considerable importance, since a gunner loses efficiency if forced to sit or lie in a cramped position for long periods of time.

Position of Guns

Guns, on the other hand, can be located at the part of the plane where they can operate

most effectively i.e., where their field of fire coverage is greatest.

Remote Control

In some installations, one gunner can control two or more turrets thus increasing effective fire power. Because undesirable compromises need not be made in locating gunners and turrets, over-all design of the plane can often be improved. For example, the gunner can be located in the pressurized part of the ship, and the guns outside this area. The amount of pressurized space required can, therefore, be reduced and the turrets can be given a more "streamlined" shape.

12. DEVELOPMENT

General

It has been stated that the two most important factors in aircraft armament applications are (1) fire coverage and (2) fire power.

General Electric Turret

The first General Electric remote-controlled turret was a purely experimental installation on a Douglas A-20 consisting of a two-gun upper and a two-gun lower turret, both mounting cal. .50 machine guns, and both controlled by one double-ended periscopic sight, as shown in Figure 6-5. The area around the upper end of the periscopic sight was covered with Plexiglas. The front of the plane was protected by its fixed forward guns. The rear, protected by the turret guns, had several weak points:

While scanning in the upper hemisphere visibility was good because of the Plexiglas, for the lower hemisphere, only the 25-degree cone of vision was available and this provided an insufficient field of view.

Firing in the upper hemisphere was restricted by the large vertical area blocked out by the fin and rudder. To overcome this, Douglas installed a "tell-tale", or fluorescent indicating screen by the pilot, which shows him when the turrets are aiming at any planes in his blind spots aft.

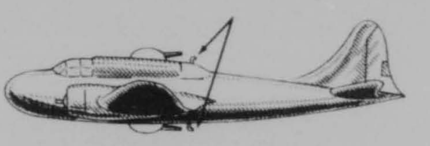

Figure 6—5. Remote Controlled Turret.

Value of General Electric Turret

This installation, though having its faults, served its purpose in developing the factors to be reckoned with in turret construction. It also served to demonstrate to the Army, on actual flight firing tests, just how practical the remote controlled turret might be.

13. PLANNED PRODUCTION

At the present time, remote-control turret systems are being produced for the following planes: The Douglas B-26 (formerly the A-26), and not to be confused with the wartime Martin B-26 light bomber, the Boeing B-29 medium bomber, the Boeing B-50 medium bomber, the Boeing B-45 heavy bomber, the North American B-47 heavy bomber, the Consolidated B-49 flying wing, the Consolidated B-36 very heavy bomber, and the Northrop F-61 night fighter.

Douglas B-26 Light (Attack) Bomber

The Douglas B-26 is a cleaned up and enlarged version of the A-20. Its primary function as an attack plane is low-altitude bombing, strafing, and fighting. The B-26 mounts a two-gun upper and a two-gun lower turret, both controlled by a double-ended periscopic sight with a rotating eyepiece. The upper turret covers the upper hemisphere except for the area interrupted by the tail surfaces, and gives an extra 5 degrees of down fire in the broadside position. The lower turret covers the lower hemisphere except where interrupted by the body of the plane, and gives a 5-degree upfire at the sides. Thus a broadside target can be tracked through the two hemispheres with overlapping fire from both turrets at the horizontal. The upper head of the periscopic sight tracks a target from the zenith down to 10-degrees below the horizontal, where the line

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of sight is switched to the lower head. The lower head follows on down to the nadir. On up-tracking, the lower head carries to 10-degrees above the horizontal before the changeover to the upper head occurs. This overlap of the sight hemisphere is to preclude frequent switching from one head to the other in cases of tracking near the horizontal. The field of view of each head has been increased to a cone of 50-degrees, a much more adequate field for scanning and tracking. Scanning in the upper hemisphere can also be done through the Plexiglas windows around the gunner's head. In addition to these four flexible cal. .50 guns, the B-26 will have fixed wing guns for offensive use, and the upper turret may be latched in a strafing position straight forward and fixed by the pilot. This arrangement of armament provides the B-26 with offensive striking power. At the same time the turrets provide sufficient defensive fire power and coverage such that with the plane's speed and maneuverability fighter protection should seldom be necessary.

Boeing B-29 Bomber

The B-29, the Air Forces medium bomber is an aircraft weighing over 100,000 pounds, with 8800 hp., a cruising range of 6,000 miles, and a bomb load of 10,000 pounds. It is a pressurized plane for high-altitude flying. The B-29 mounts five turrets: the upper four-gun turret in the forward section, the upper aft two-gun turret, the lower forward two gun turret, the lower forward two gun turret, the lower aft two gun turret, and the tail turret (mount) which contains two cal. .50 machine guns. On the B-29 airplane, there are five sighting stations located so as to afford the maximum unobstructed view on all sides of the airplane. A "sighting station," as the term is used in this book, refers to the actual sighting equipment, i.e., the sight and accessory equipment used by a gunner in tracking a target and in operating remotely located gun turrets. More specifically, a sighting station comprises a sight, a means of moving the sight in azimuth and elevation, a means of indicating to a gun turret the precise direction in which the sight is pointing, and a means of transmitting to the computing system variations in range and lead.

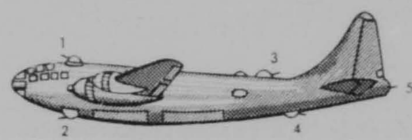

Figure 6–6. Douglas A-26 Attack Bomber.

As can be seen in Figure 6-6, the five sighting stations on the B-29 airplane are located as follows:

One on the upper structure of the ship, forward of the upper-rear turret, called the "ring sighting station."

One in the tail of the ship called the "tail sighting station."

Two located in blisters (one on each side of the ship) just forward of the rear gun turrets, and called the "right-blister sighting station" and the "left-blister sighting station," respectively.

One in the nose of the ship, called the "nose-sighting station."

The B-50 fire-control system is identical to that of the B-29.

14. THE FOLLOW UP SYSTEM

Introduction

The operation of a turret from a remotely located sighting station requires a control system in which the motion of the sight is duplicated by the turret guns. This control system is referred to as the "follow-up system," and is described in the paragraph below. In addition to the follow-up system, the complete central-station fire-control system requires auxiliary circuits such as starting circuits for the rotating machines, limit-switch circuits, backout circuits, firing circuits, transfer circuits, etc. Those circuits are as important as the follow-up system, and hence a few of them are discussed in publications dealing with specific airplanes.

Principles of Operation

One-speed system. While positioning of the

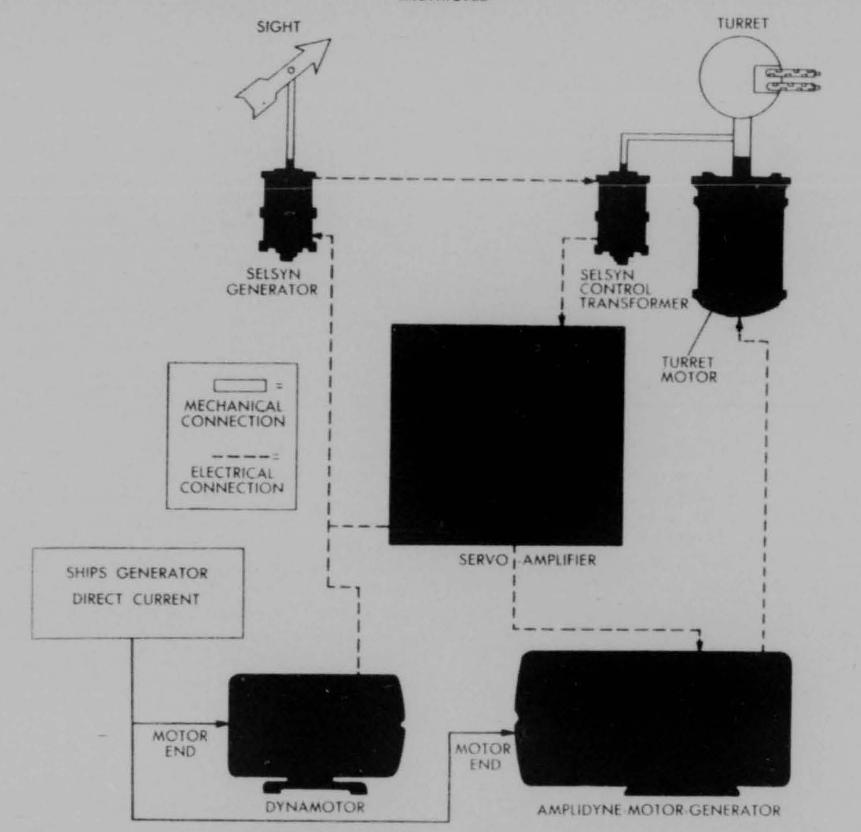

Figure 6–7. Rotor of Selsyn Generator.

gun requires control of motions in azimuth and elevation, the follow-up system is the same for both motions and, therefore, only one motion, azimuth, is discussed. The following paragraph presents a nontechnical version of the operation of the follow-up system.

In Figure 6-7, the rotor of a Selsyn generator is geared to the azimuth motion of the sight. This generator is a small electric device having windings on its rotor and stator. Geared to the azimuth motion of the turret is a Selsyn control transformer, which is similar, but not identical to the Selsyn generator. The Selsyn generator is supplied with alternating current from a small motor-generator

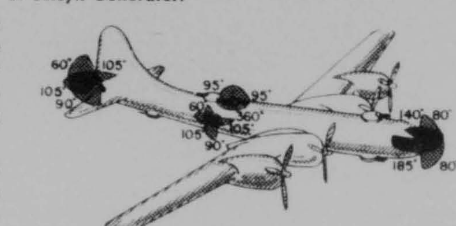

Figure 6–8. Five Sighting Stations on B-29.

set (dynamotor) and is electrically connected to the Selsyn control transformer. When so connected, the Selsyn generator transmits electrically the azimuth position of the sight

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to the Selsyn control transformer. The Selsyn control transformer, in turn, compares the azimuth position of the sight with the azimuth position of the turret to which it is geared. If any difference in position exists, an "error signal" appears across the terminals of the signal transformer. This "error signal" is then fed into a vacuum-tube amplifier (servo-amplifier), where it is converted into a signal capable of controlling the output of a DC generator (amplidyne generator). The output of this amplidyne generator as controlled by the signal from the servo-amplifier is fed into the turret-drive motor, causing the motor to drive the turret and the rotor of the Selsyn control transformer toward alignment with the sight. When the turret comes into alignment, the "error signal" across the signal transformer will disappear, and the output of the amplidyne generator will go to zero, allowing the turret to come to rest, aligned with the sight.

Component Parts

Power Supply. The primary source of power for the turret system and all other electric equipment is the aircraft generator, which is driven directly by the aircraft engine. The aircraft generator, and associated battery, supply the airplane with a constant source of approximately 28-volts DC.

Dynamotor. The Selsyn and the servo-amplifier used in this system require a source of alternating current. Some means of converting the direct-current power of the airplane into alternating current is necessary. The most practical way to supply the required alternating current is by use of a dynamotor, which is nothing more than a motor-generator set.

Selsyn Generator. The function of the Selsyn generator, which is coupled mechanically to the sight, is to transmit electrically the position of its rotor with respect to its stator. The rotor consists of a single-coil winding excited from the AC power supplied by the dynamotor. The stator consists of a winding so arranged that it produces an output signal which transmits to the Selsyn control transformer the position of the Selsyn generator rotor.

Selsyn Control Transformer. The function of the Selsyn control transformer is to receive an electrical signal which indicates the position of the Selsyn generator rotor and to compare the position of this generator rotor with the position of its own rotor. The Selsyn control transformer is similar in external appearance to the Selsyn generator, but its internal construction is slightly different, and they are not interchangeable.

Servo-amplifier. The "error signal" from the rotor of the control transformer is a low-power AC signal. This signal is fed into a vacuum-tube amplifier, called the servo-amplifier, which rectifies, amplifies it, and feeds it into the control field of the amplidyne generator.

Amplidyne Motor-generator. The amplidyne motor-generator consists of a DC shunt motor built on the same shaft with an amplidyne generator. The motor is energized from the airplane's power supply. The amplidyne generator is similar in operation to an ordinary DC generator, with the exception of two features: In the amplidyne generator, the output voltage builds up to its final value in a very short time, and a very small field current of only a few milliamperes, is required to produce full voltage.

Turret-drive Motor. Since the turret must be capable of rotation in either direction, i.e., clockwise or counterclockwise, the motor which drives the turret must likewise be capable of rotation in either direction. A separately excited DC motor is used because the direction of rotation can easily be reversed. With the field of the turret motor excited from the airplane's 28-volt power supply, the direction of rotation of the turret will depend upon the polarity of the output voltage of the amplidyne which is supplied to the armature of the motor. Another feature of the separately excited motor is that it has a high starting torque with relatively small armature currents.

The Two-signal System

Selsyn generators differential generators, and control transformer Selsyns are subject to a small electrical error due to manufacturing irregularities in the windings and in the

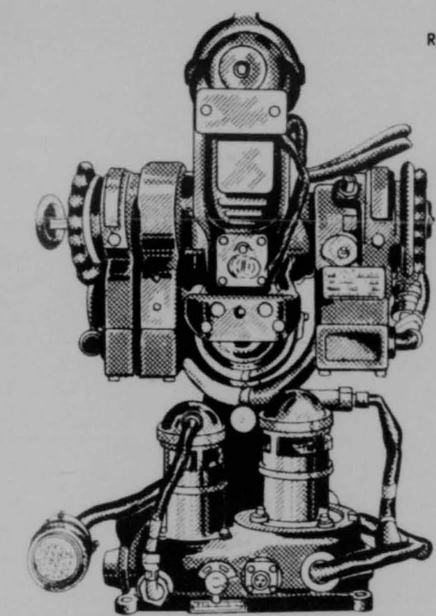

Figure 6–9. Pedestal-Type Sighting Unit Model 2CSR3B5.

magnetic structure. To obtain the high degree of accuracy desired, it is common practice to use Selsyns which are geared to rotate at speeds higher than those of the turret or sighting stations. A Selsyn is sometimes not more accurate than one-half of a degree. Such an error, of course, is too large to be tolerated in a gun-sighting system. To avoid this, two sets of Selsyns are used, each set consisting of a generator Selsyn and a control transformer Selsyn are used to control each motion. In the turret follow-up system, a one-speed Selsyn system and a 31-speed Selsyn system is used. The Selsyns in this 31-speed system are geared to rotate at 31 times the speed of the sight and turret to which they are mechanically coupled. The one-speed Selsyns are geared so that the rotors of the generators and control transformer Selsyns make one revolution for each revolution of the turret and sighting station. The system is so arranged, that, for large sight-and-turret misalignment, the one-speed Selsyn takes control and causes the turret-drive motor to drive the turret to within approximately 3-degrees of alignment with the sight. The 31-speed Selsyn system then takes control automatically, and drives the turret until the 31-speed Selsyn rotors are in correspondence. Thus, an error of ½ degree in the Selsyn system represents an actual gun alignment error of only 1/62 degree at the turret, and reduces the amount of error which would be expected from the simple one-speed system. It is, of course, possible to utilize a one-signal, 31-speed system, but when a 31-speed control is used, there are 31 positions of the turret for which the Selsyn system may indicate electrical correspondence. At only one of these 31 positions of electrical correspondence would the sight be in alignment with the turret. It is to avoid this effect that a two-signal system is used.

15. SIGHTING STATIONS

General

There are several types of sighting stations used with the central-station fire-control system. The basic operating principle of each is exactly the same. A sighting station comprises a sight, a means of indicating to a gun turret the precise direction in which the sight is pointing and a means of transmitting to the computing system variations in range and lead. On the B-29 airplane there are two types of sighting stations, ring and pedestal, located so as to afford the maximum unobstructed view on all sides of the airplane. (Figure 6-8.) The five sighting stations are well located to provide the best possible coverage from any particular gunner's station.

Retiflector Sights

In the case of the B-29 airplane, each sighting station has as one of its major parts a retiflector sight, the purpose of which is to frame the target and at the same time send a range prediction to the computer. Each sighting station on the B-29 is moved manually in azimuth and elevation by the gunner. The Selsyn system provides the means of indicating the position of the sight to the turret.

16. COMPONENTS

The first sighting station to be covered is the pedestal type (Figure 6-9), of which there are four on the B-29. Each pedestal-type sighting station is made up of four major assemblies, namely: the azimuth assembly, the elevation assembly, the retiflector sight assembly, and the gyro and support assembly. (Figure 6-11.)

17. DETAILED DESCRIPTION: THE AZIMUTH ASSEMBLY

Function

The azimuth assembly (Figure 6-10) actually forms the base for the pedestal-type sighting station. However, it also transmits signal voltages from Selsyn generators on the sighting station, through the computer to the azimuth-Selsyn control transformers on the turret or turrets. These signal voltages indicate the exact position of the sight in azimuth.

Major Parts

The major parts of this assembly are two Selsyn generators (a one-speed unit and a 31-speed unit); two gear trains, one for each Selsyn generator; and a cast-aluminum-alloy gear housing. The Selsyn units mount on the gear housing which also supports (by means of a shaft, or vertically-extended bearing support) the yoke of the elevation assembly. Also located on the gear housing are the computer-standby switch, the azimuth stowing pin, the azimuth-limit stops, the reticle-adjustment rheostat, and the azimuth-friction screw.

The 31-speed Selsyn unit is mounted in the following manner: its flanged end shield (on the shaft end) fits snugly into a rabbeted recess in the top of the gear housing. It is held securely in place by three clamps. The clamps, which fit over the edge of the Selsyn's flanged end shield, are held by three lock washers and screws which fit into tapped holes in the gear housing. (Figure 6-12.)

The one-speed Selsyn is attached to a mounting plate by similar clamp and screw assemblies. The plate is held in place on top of the gear housing by four safety-wired screws.

Gear Trains. (Figures 6-11 and 6-12.) An input spur gear on the end of the yoke shaft meshes with an identical spur gear attached to the rotor of the one-speed Selsyn generator.

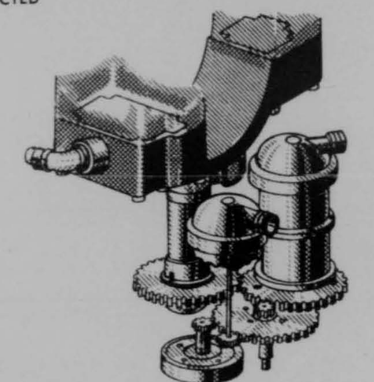

Figure 6-10. Azimuth Selsyn Gearing. Model 2CSR3B5.

Thus, as the yoke is rotated in azimuth, the rotor of the one-speed Selsyn unit makes one full revolution for every full revolution of the yoke. At the same time, the spur gear on the rotor shaft of the one-speed Selsyn serves to drive the gear train for the 31-speed Selsyn generator. This is acomplished in the following manner. The one-speed Selsyn spur gear engages a pinion on a sha. which also carries an intermediate spur gear. In turn, the intermediate spur gear meshes with a pinion on the rotor of the 31-speed Selsyn generator. A bearing plate supports the inertia-wheel shaft and pinion as well as the shaft which carries the intermediate spur gear. The gear ratio of the train is such that the rotor of the 31-speed Selsyn generator will make 31 complete revolutions for each 360-degree rotation of the yoke. The intermediate spur gear also drives a pinion whose shaft carries an inertia wheel. The "flywheel action" of this inertia wheel tends to smooth out the movement of the movement of the sighting station as it is rotated in azimuth but is designed to allow quick starts or stops. Ball-bearing assemblies assure freedom of rotation for all shafting used in the gear train.

Computer-Standby Switch

(Figure 6-12.) This is a luminous toggle-type switch which is mounted on the front of the azimuth-Selsyn gear housing. Nameplates identify it clearly and show the "in" position. The switch serves as a means of allowing the

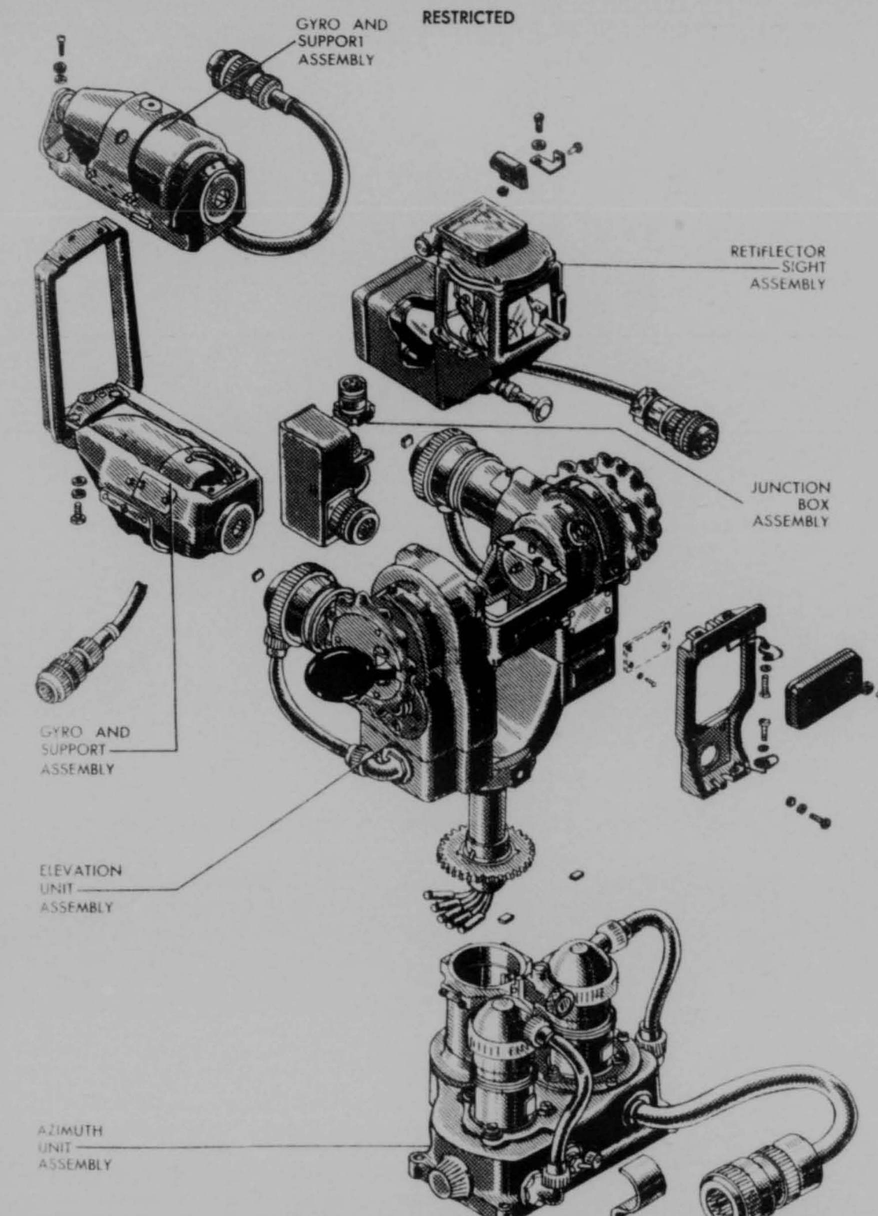

Figure 6-11. Major Parts of Pedestal Sight.

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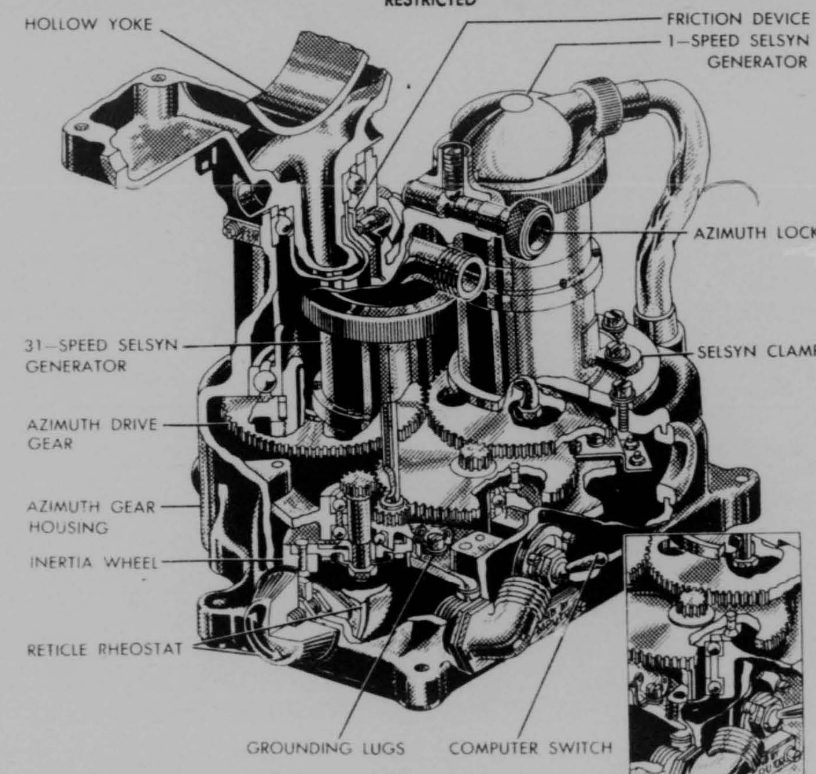

Figure 6—12. Cutaway View Azimuth Assembly Showing Gears, Shafts, etc.

Selsyn signal from the sight to by-pass the computer and go directly to the Selsyn control transformers on the turret. This switch could be used to make the system non-computing should the computer be damaged by gunfire.

Azimuth Stowing Pin

This assembly, (Figure 6-12) which is used to stow the sighting station in any one of three positions in azimuth, is located between the two Selsyn units on the front of the bearing support for the yoke. A ball, spring, and limit-screw assembly is used to hold the pin in its "out" or "in" position.

Limit Stops

The stops which limit rotation of the sighting station in azimuth are located on the same portion of the casting that houses the stow-pin assembly. Two metal clamps, one on either side (and to the rear) of the stow-pin assembly, carry rubber snubbers which engage ears on the yoke and thus stop rotation on the sight in azimuth when it has reached its limits of travel.

Reticle-adjustment Rheostat

(Figure 6-12.) This is located on the left-hand side of the gear-housing casting and is used for increasing or decreasing the brightness of the reticle image. The adjustment is made by means of a black composition knob, clearly marked with a white arrow and the words "on" and "off."

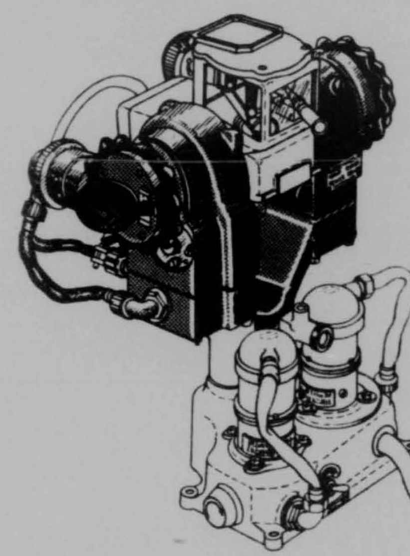

Figure 6—13. Elevation Assembly Pedestal Sight.

18. THE ELEVATION ASSEMBLY

Function

The function of this assembly (Figure 6-13) is to mount the retiflector sight and serve as a means for permitting movement of the sight in elevation. The elevation-Selsyn-generators, also located on the assembly, transmit signal voltages from the sighting station, through the computer to the elevation-Selsyn control transformers on the turret, or turrets, controlled by the sighting station. These signal voltages, indicate the exact position of the sight in elevation.

Major Parts

The major parts of the elevation-Selsyn-generator assembly are: two Selsyn generators (a one-speed unit and a 31-speed unit); two handwheels by means of which the gunner moves the sight in elevation; two gear trains for connecting the rotors of the Selsyns with the handwheels; a main yoke which carries the entire elevation-Selsyn-generator assembly; a yoke for supporting the retiflector sight; two gear boxes which mount on the main yoke; house the gear trains, and mount the Selsyn units; two triggers for firing the guns; an action switch and a range handle which are carried on the left and right handwheels respectively; two gyroscopes (not shown) which mount above and below the retiflector sight, respectively; an elevation-friction screw, which is located on the right-hand gear box; and an elevation stow pin located in the rear of the sight on the right-hand side of the main yoke.

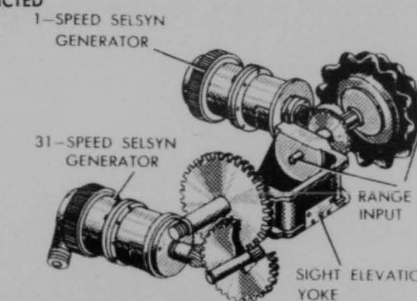

Figure 6—14. Schematic Drawing Showing 1 and 31-Speed Elevation Selsyn Drive Gearing and Range Input, etc.

Selsyn-generator Units. The elevation-Selsyn generators are identical in construction to those used on the ring-type sighting station. The only difference lies in their zero position with respect to the sighting station. The 31-speed Selsyn is mounted on the rear of the left-hand gear box (as the gunner looks into the retiflector sight) in the following manner: the shaft end of the Selsyn fits into a rabbeted recess in the gear-box casting and is held in place by three clamps, lock-washers and screws. The one-speed Selsyn generator is attached to the right-hand gear box in the same manner as the 31-speed Selsyn. Electrical connections to both of these Selsyns are made through Selsyn caps, which screw onto the Selsyn generators.

31-speed Selsyn Gear Train. This assembly (Figures 6-14 and 6-15) is housed in the left-hand gear box (as the gunner looks into the retiflector sight) and connects the left handwheel with the rotor of the 31-speed Selsyn generator. This is accomplished in the following manner. The left handwheel is mounted on the end of a hollow drive shaft, supported at either end by ball-bearing assemblies

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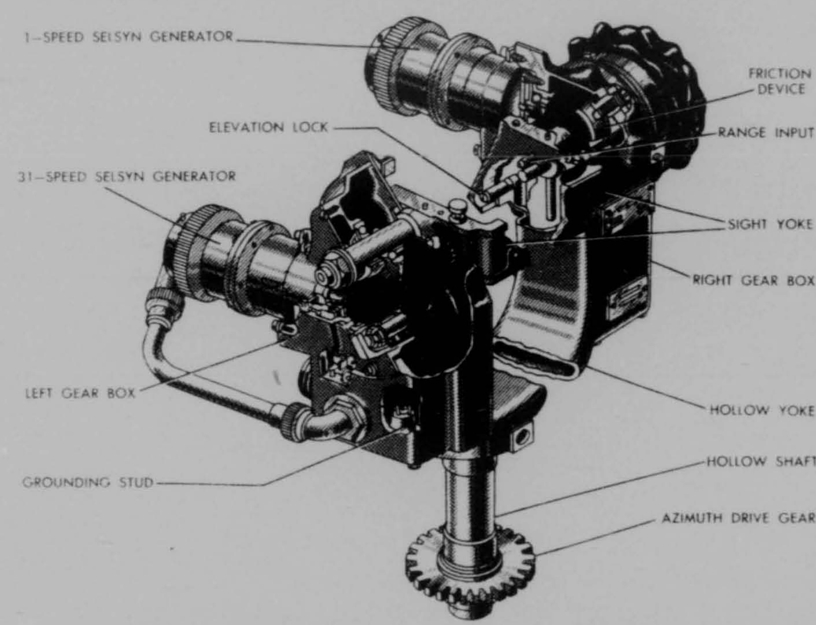

Figure 6—15. Cutaway View of Elevation Assembly Showing Drive Gearing Shafts and Bearings.

which, in turn, fit into opposite sides of the gear box. The end of this shaft opposite to the handwheel attaches to the yoke which carries the retiflector sight. Thus, as the gunner rotates the handwheel, the sight yoke (and, therefore, the retiflector sight) is raised or depressed. Inside the gear box, a large spur gear attached to the hollow drive shaft, engages a pinion on an intermediate shaft-and-gear assembly. Also mounted on this intermediate shaft is a large bevel gear which meshes with a small bevel gear on a short shaft which drives the rotor of the 31-speed Selsyn by means of a simple coupling. Thus, as the gunner elevates or depresses the sight, the gear train turns the rotor of the 31-speed Selsyn. The gear ratio of this train is such that the rotor of the 31-speed Selsyn generator makes 31 complete revolutions for each single revolution of the handwheel. Ball-bearing assemblies provide freedom of rotation for the gear shafts.

One-speed Selsyn Gear Train. (Figures 6-14 and 6-15.) As in the case of the left handwheel, the right handwheel is also mounted on a hollow shaft supported by a ball-bearing assembly which fits into a recess in the side wall of the right-hand gear box. In this case, also, the shaft extends through the side wall of the gear housing and is part of the sight yoke. Thus, the gunner can rotate this handwheel and elevate or depress the retiflector sight. Inside the gear box, the hollow shaft mounts a large bevel gear which engages directly with an identical bevel gear mounted on one end of a shaft, the other end of which carries a simple coupling. The coupling connects with the rotor of the one-speed Selsyn. Thus, because both bevel gears are identical, one complete revolution of the handwheel will cause one complete revolution of the rotor of the one-speed Selsyn.

The Main Yoke. (Figures 6-10 and 6-15.) This is a hollow Y-shaped yoke whose single

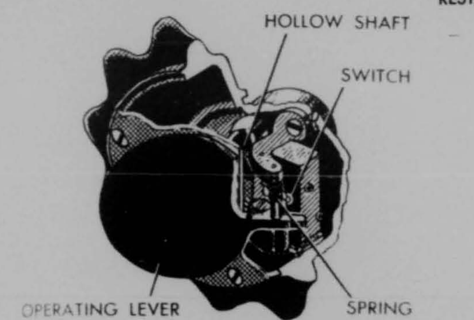

Figure 6—16. Cutaway View of Action Switch Mechanism.

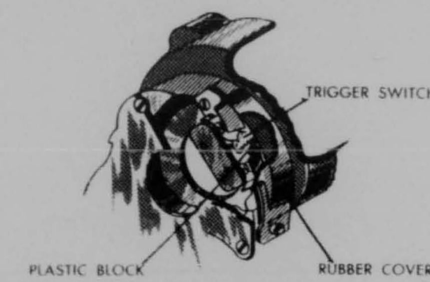

Figure 6—18. Cutaway View of Left Trigger Switch.

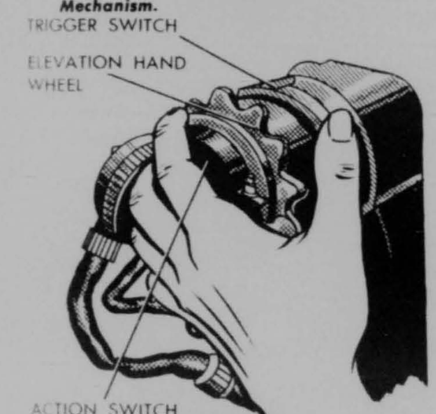

Figure 6—17. Left Hand in Place on Elevation Handwheel and Action Switch.

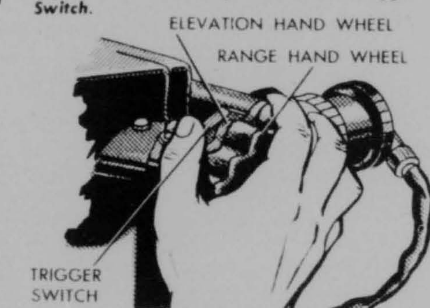

Figure 6—19. Right Hand in Place on Elevation Handwheel and Range Input Handwheel.

(lower) end is a hollow shaft which fits into the extending bearing support on the azimuth assembly. The spur gear, keyed to its lower end, engages the gear train of the azimuth-Selsyn-generator assembly so that when the yoke is rotated the azimuth gear train is set in motion. The yoke, itself, is an aluminum-alloy casting which mounts on its arms two gear boxes which carry the elevation-Selsyn generators. The wiring for the electrical units, supported by the yoke, is brought into the elevation assembly through the yoke's hollow shaft and hollow arms.

The Sight Yoke. The sight yoke (Figures 6-13 and 6-15) used to mount the sight is also a U-shaped aluminum-alloy casting. This yoke pivots between the arms of the main yoke and is supported (with the bottom of the U towards the gunner) by the two drive shafts from the right and left handwheels. Two pins on the sight-mounting surface assure proper alignment of the sight. The front of the yoke is drilled and tapped to support a front bracket which, in turn, supports one end of both gyroscope units. The mounting surface for the front bracket has two pins to assure proper alignment of the bracket and hence the gyroscopes. Mounted on the sight yoke are the stops which limit the travel of the sight in elevation. A hole in the rear-right arm of the sight yoke engages the elevation-stow pin by which the sight is stowed.

Action Switch. (Figures 6-16 and 6-17.) This disk-like switch is mounted on the left handwheel. It is held in normally open position by a spring assembly. When the gunner closes it by pressing it with his palm, (if the control box switches are properly positioned) the guns on the turret will swing into alignment with the gunner's line of sight. Wiring

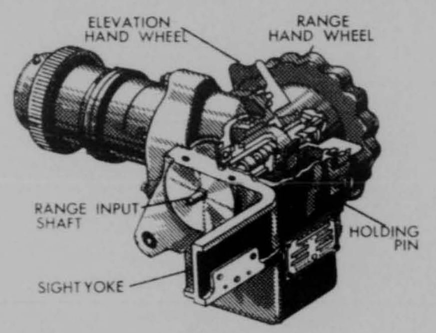

Figure 6—20. Cutaway View of Range Input Mechanism.

for the action switch is brought into the elevation assembly through the hollow yoke and reaches the action switch through the hollow drive shaft carrying the left handwheel. A slot in this drive shaft permits entry of the wiring and the fact that the sight can only be rotated a total of 150 degrees in elevation prevents undue twisting of the wiring.

Firing Triggers. (Figures 6-18 and 6-19.) The two firing triggers are mounted on the front of the right- and left-hand gear boxes in a convenient position for the gunner to press them with his thumbs. Pressure on either trigger will actuate a relay which, in turn, closes the firing circuit to the guns and, provided the gun switch on the control box is in the "fire" position, the guns will immediately begin to fire.

Range Handle. This handle is similar in contour to the right handwheel on which it is mounted. As shown in Figure 6-20, the range handle is mounted on a grooved shaft which extends through the hollow drive shaft of the one-speed-Selsyn-generator assembly and connects with the retiflector sight's gear train. The range handle is held in place by a spring-actuated pin, engaging grooves in the shaft.

Elevation-friction Screw. (Figure 6-15.) This device, which is the means by which the gunner adjusts the sighting station for freedom of movement in elevation, is located on the front of the right-hand gear-box casting. Tightening or loosening of the screw increases or decreases pressure on a metal shoe with felt liner which rides on the drive shaft rotated by the right handwheel. A lock nut

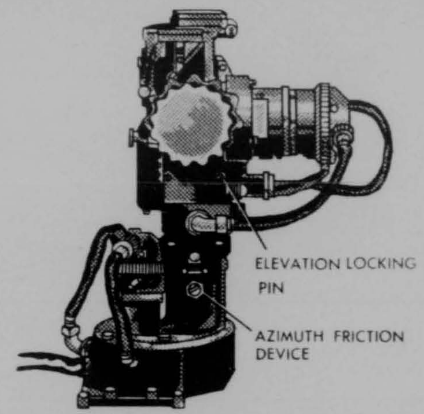

Figure 6—21. Right Hand Side of Pedestal Sight Unit Showing Elevation Locking Pin, Azimuth Friction Device.

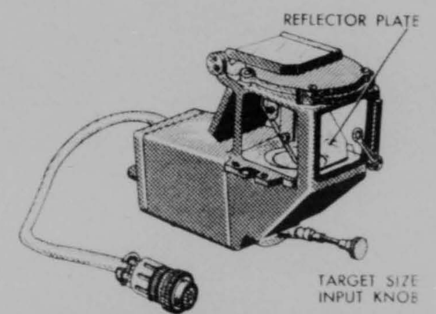

Figure 6—22. Retiflector Sight Mounted on Pedestal Sighting Unit.

holds the screw in position after the friction adjustment is complete.

Elevation-stowing Pin. (Figure 6-21.) This assembly, which is used to lock the elevation assembly when stowing the sighting station, is located at the rear of the right-hand gear box. It consists of a pin which mounts in a flange on the gear-box casting and which can be slid into a hole on the rear of the sight yoke to lock the sight yoke in the horizontal position. A ball, spring, and screw assembly (similar to that used on the azimuth-stow pin) keeps the pin in proper position.

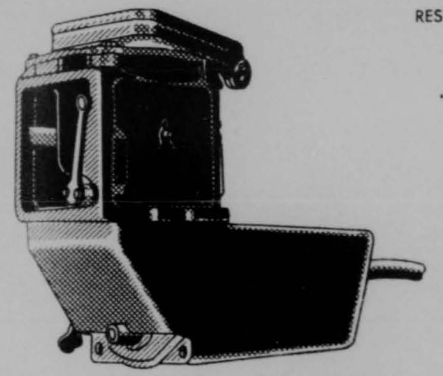

Figure 6—22A. Retiflector Sight with Blinders.

Note: The proper spring tension is set at the factory and should not be changed.

19. RETIFLECTOR SIGHT

Mounting

The retiflector sight, (Figure 6-22) is mounted on the sight yoke. (Figure 6-23.) It is identical to the sight used on the ring-type sighting station with two minor exceptions.

On the model A, C and E sights used on the pedestal-type sighting station, the assembly containing the reflecting glass and the sky filters is attached to the unit at a point 90 degrees in a clockwise direction (as shown in figure 6-22-A) from its location on the model B sight.

The target-size-input shaft is lengthened by inserting an adapter between the knurled input knob and the sight case.

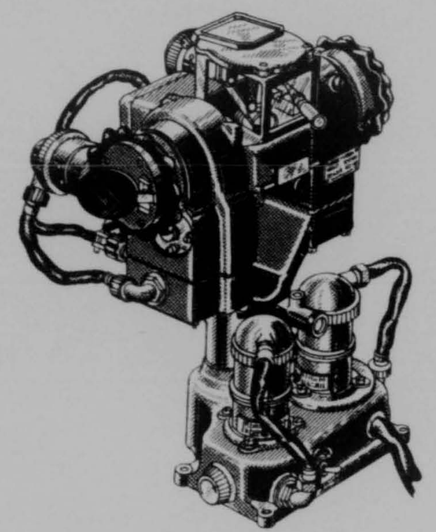

Figure 6—23. Retiflector Sight

Note: The model E retiflector sight has an 18-dot reticle for ranges below 700 yards, 12 dots for ranges above 1300 yards. The dots are slightly smaller than on previous sights. An internal range scale visible on the object glass is provided. The target size setting can be varied from 15 to 75 feet. It is interchangeable with models A and C.

SECTION II—RING SIGHTING STATION

1. THE UPPER-SIGHTING STATION
(Figures 6-24 and 6-25.)

General

The upper-sighting station, model 2CSR-3A1, is located on the upper structure of the airplane just forward of the upper-rear turret. This sighting station is called the "ring type." It takes its name from the fact that it is fastened to the structure of the airplane by means of a ring assembly which also forms a track in which the sight is moved in azimuth. When using the sight to follow the movements of a hostile airplane, the gunner is seated in a swivel seat elevated from the floor so that his eyes are slightly above the level of the fuse-

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Figure 6—24 Upper Gunner in Position at Ring-type Sighting Station.

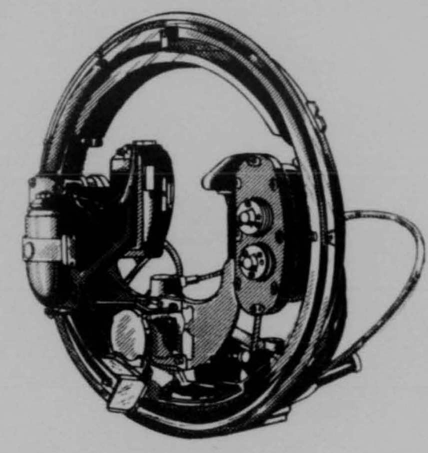

Figure 6—25. Upper Sighting Station.

lage. (Figure 6-24). He operates the sight by moving it manually in both azimuth and elevation. The gunner uses the platform on which his feet rest to facilitate rotating his swivel seat. Power to operate the various electric units on the sighting station is brought in by means of the collector-ring assembly which is located inside the base of the support for the gunner's seat.

The Blister

Covering the sighting station is a stationary, transparent dome, or "blister," which affords the gunner an unobstructed view of the entire hemisphere above the airplane.

Limits of Sight Movement

The upper-sighting station can be rotated continuously in either direction in azimuth, and 95 degrees in elevation from the vertical to 5 degrees below the horizontal.

2. BASIC PARTS OF THE UPPER-SIGHTING STATION
(Figure 6-26.)

The upper-sighting station is composed of eight major parts or assemblies. These are defined as follows:

The Ring Assembly

This consists of two rings, an outer and an inner ring. The inner ring, which supports the retiflector sight and its various accessories rides on the outer ring which serves as a means of mounting the sighting station on the airplane structure. The ring assembly is also the means of permitting the sight to swing in azimuth.

The Control Unit and Junction Box

This device, by which the gunner actually operates the sight, attaches to the inner ring and is composed of the following parts: the range grip, the action switch, the trigger, the interphone button, the reticle-lamp adjustment knob, the computer switch, and the azimuth and the elevation stowing pins.

The Azimuth Selsyn-generator Assembly

This is the means of transmitting to the turrets, signal voltages which indicate the position of the sight in azimuth.

The Elevation Selsyn-generator Assembly

This assembly transmits to the turrets, signal voltages which indicate the position of the sight in elevation.

The Yoke Assembly

This assembly mounts the sight, and is pivoted between the azimuth and elevation Selsyn-generator assemblies.

The Retiflector-type Sight

This is a direct-vision type of sight through which the gunner looks when tracking his target.

The Gyroscopes

There are two single-action gyroscopes, one for azimuth and one for elevation. These are mounted on the right-hand arm of the yoke. The gyroscopes serve as a means of transmitting to the computer the necessary electrical corrections for lead.

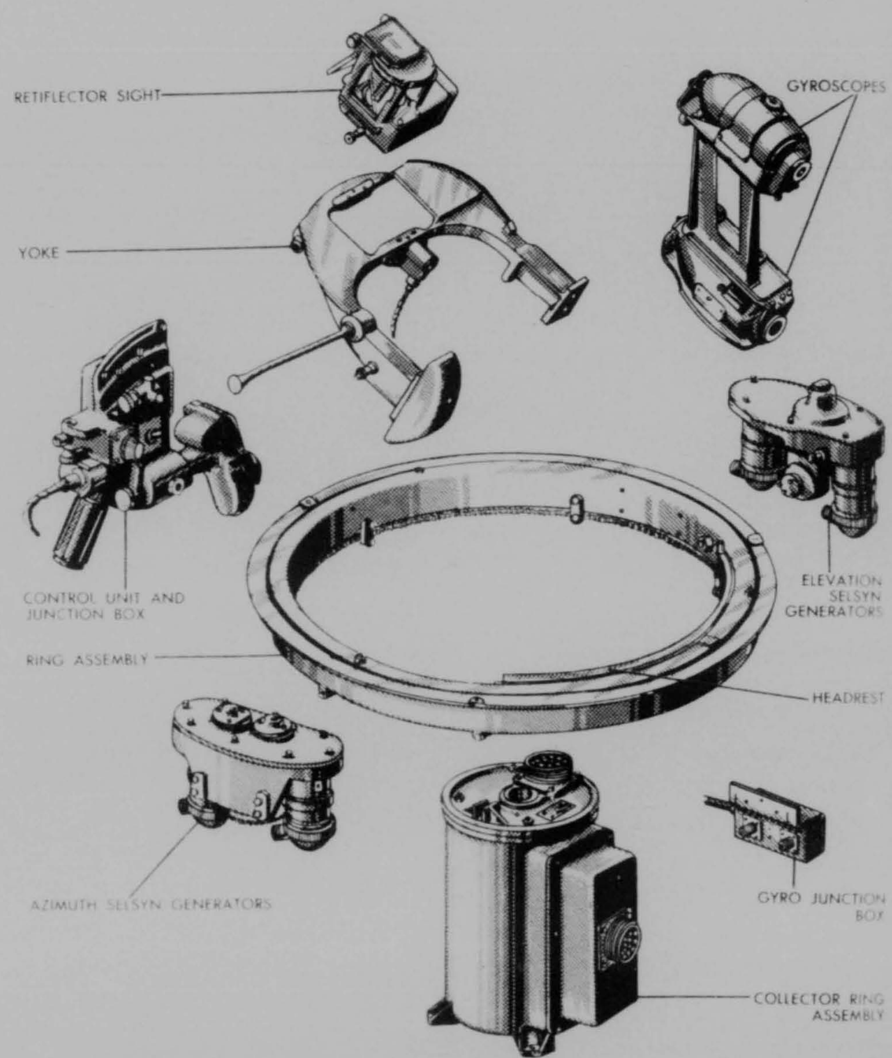

Figure 6—26. Major Parts, Ring-Type Sighting Station.

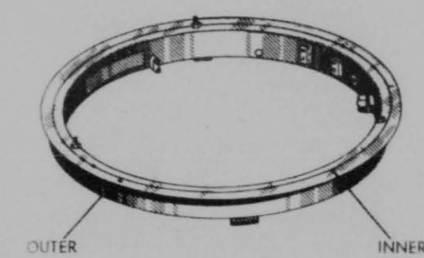

Figure 6—27. Outer and Inner Rings Assembled.

Collector Assembly

The collector assembly is housed inside the support which carries the gunner's seat. It serves as a means of bringing power from the airplane's electrical system to the sighting station.

3. THE RING ASSEMBLY
(Figure 6-27.)

As in the case of the turret, the ring assembly on the upper-sighting station essentially comprises two rings, one of which turns inside the other by means of radial and trust bearings. The outer ring is the means of fastening the sight to the airplane structure while the inner ring supports the rest of the sighting station sight and much of the sight's accessory equipment.

The Outer Ring

This is a ring which is Z-shaped in cross-section (Figure 6-28.) The upper flange is drilled to take the mounting bolts which fasten the sighting station to the airplane's structure. The lower flange has teeth cut on its inner periphery. These teeth are engaged by the drive gear on the azimuth Selsyn-generator assembly.

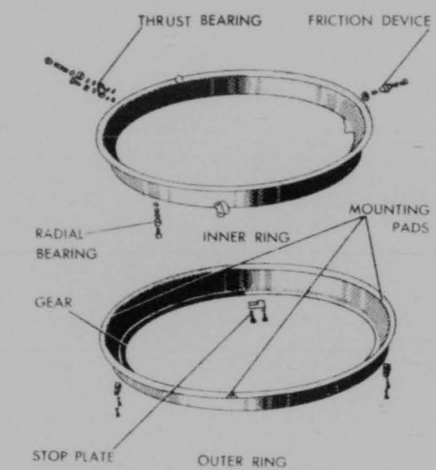

Figure 6—28. Outer and Inner Rings Separated.

The Inner Ring

This is a ring which has an inverted-L cross-section (Figure 6-28. The flange (upper) portion of the ring mounts three radial bearings. The side portion of the ring mounts the following parts: five double thrust bearings, the azimuth-friction device, the azimuth and elevation Selsyn-generator assemblies and the control and junction-box assembly.

Ring Bearings

Ball bearings mounted on short shafts,

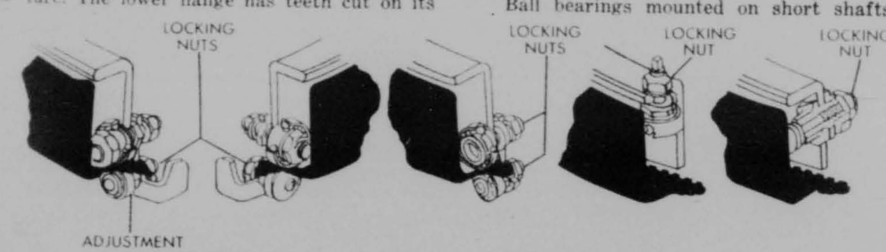

Figure 6—29 Sectional View of Rings Showing Bearings and Friction Device.

bolted to the inner ring, ride on machined surfaces on the outer ring. Five thrust bearings support the inner ring within the outer ring. Three radial bearings center the inner ring within the outer ring and serve to maintain the alignment between the two rings.

Each thrust bearing assembly consists of an upper and lower ball bearing. The upper bearing rides on the top of the inside flange of the outer ring. The lower bearing rides on the under side of the same flange. (Figure 6-29 The upper bearing in each assembly carries the weight of the sighting station, and the lower bearing prevents upward motion. The spacing between upper and lower bearings can be adjusted to maintain the proper clearance between the lower bearings and the under side of the flange. One of the thrust bearings (Figure 6-29) is located on the ring back of the elevation Selsyn-generator assembly. These two bearings are equipped with brackets having sections turned at right angles to prevent complete rotation of the sighting station in azimuth without rotation of the gunner's seat. This is to aid the gunner in maintaining the most effective sighting position.

A third bearing of similar construction but without the right-angle bracket is located to the right of the control unit and junction box assembly on the inner ring. All three of these thrust-bearing assemblies are adjusted by loosening the locking nut, turning the adjustment and then tightening the locking nut. The shaft is eccentric, thus turning the adjustment raises or lowers the lower bearing to give the clearance desired.

Two additional thrust bearings (Figure 6-29) are located on the inner ring above the point where the control unit and junction-box assembly is mounted. These give additional support to the inner ring at the point where the gunner is likely to apply stress to the ring These two thrust-bearing assemblies are also adjustable. In this case, however, both the upper or lower bearing of each assembly can be adjusted. The lower bearing is adjusted in the same way as the lower bearings previously described. The upper bearing is adjusted by loosening the lock nut on the bearing shaft, turning the shaft (which is eccentric) with a screwdriver, and then tightening the nut to hold the adjustment.

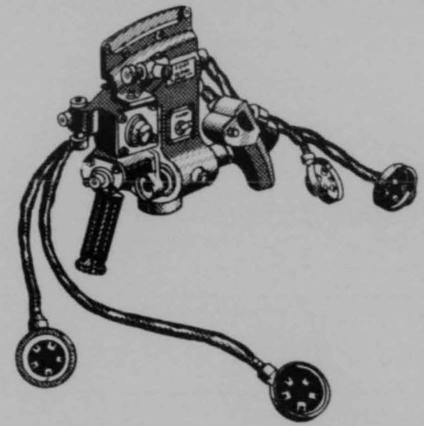

Figure 6—30. Control Unit and Junction Box.

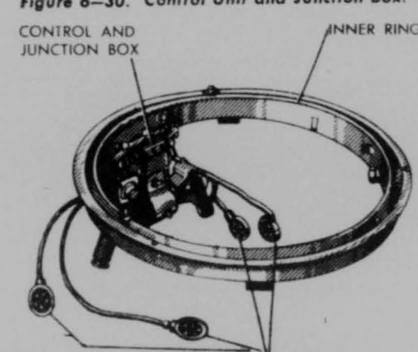

Figure 6—31 Control Unit and Junction Box Mounted on Inner Ring.

The centering of the inner ring is accomplished by three radial bearing assemblies equally spaced and mounted on the horizontal section of the inner ring. (Figure 6-29d.) These bearings also have eccentric shafts to permit radial positioning and accurate centering of the inner ring with the outer.

Friction Device

Figure 6-29 shows an adjustable spring-loaded friction device mounted on the inner ring to aid in controlling motion in azimuth. The amount of friction can be adjusted by turning the shaft with a screwdriver. The friction setting can be maintained by tightening the local nut on the shaft.

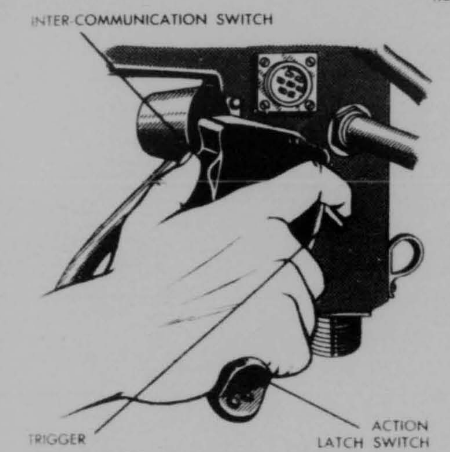

Figure 6—32. Right-Hand Grip Showing Action Switch, Intercommunication Switch and Trigger Switch.

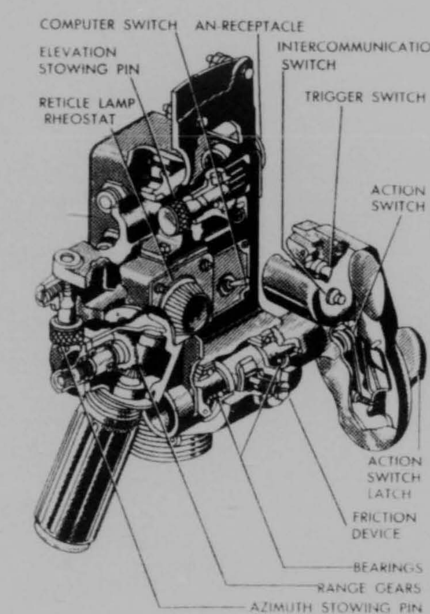

Figure 6—33. Cutaway View of Control and Junction Box Assembly Showing Shaft Bearings, Friction Device and Range Adjustment Gearing.

4. CONTROL UNIT AND JUNCTION-BOX ASSEMBLY

Control of the line of sight in azimuth and elevation is effected through the right-and-left hand grips which form parts of the control and junction-box assembly. (Figure 6-30.) This assembly is attached to the inner ring as shown in Figure 6-31.

Right-hand Grip

(Figure 6-32.) An action switch to apply power to the gun turret, or turrets, is located on the right-hand side of the grip. The gunner holds the switch closed against a spring by depressing the switch lever with the side of his hand. His hand fits between the grip and lever, and not over the lever. Located at the top of the grip is a trigger which is operated by the first or index finger. Also on the grip, and in position to be operated by the thumb, is a push-button switch for the inter-communication circuit of the plane.

Left-hand Grip

This is the range adjusting grip. It is connected to a flexible shafting by means of the gearing shown in Figure 6-33. The flexible shafting is connected to the retiflector sight.

Housing

(Figure 6-33.) The housing is an aluminum alloy casting, which carries two ball bearings supporting a shaft on which are mounted the right-hand grip and the left-hand (or range-adjusting) grip together with gearing and a flexible shaft connection to the retiflector sight. This range grip also serves as a connection point for a link or rod connection to the yoke. The casting also supports an adjustable friction device which bears upon the shaft midway between bearings. This device aids in smoothing the operation of the sight in ele-

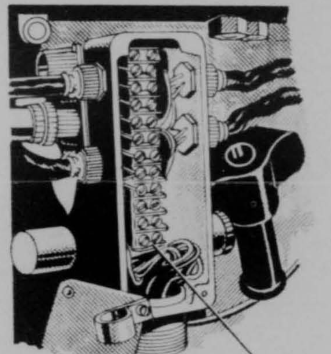

Figure 6–34. Junction Box Side of Control and Junction Box Assembly.

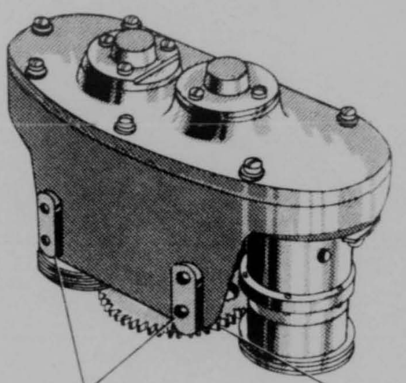

Figure 6–35. Azimuth Selsyn Generator Assembly Showing Mounting Pads and Drive Gear, Ring-Type Sighting Unit.

vation. The casting also provides a mounting for a computer stand-by switch and for a combined switch and rheostat for the sight's reticle lamp.

Junction Box

All electrical connections for the sighting station are brought from the collector assembly (located under the gunner's swivel seat) to a terminal board mounted in the housing. (Figure 6-34.) From the terminal board, connections are carried to the various electrical units on the sighting station.

Stowing Pins

There is an azimuth stowing pin to lock the yoke assembly in the horizontal position, and an elevation stowing pin to lock the inner ring at "forward," "broadside," or "aft" position in azimuth. (Figure 6-33.)

5. AZIMUTH SELSYN-GENERATOR ASSEMBLY

(Figures 6-35, 6-36, and 6-37.)

Function

The azimuth Selsyn-generator assembly is bolted to the inner ring of the sighting station

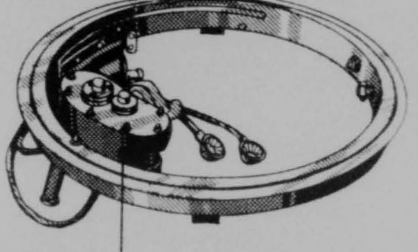

Figure 6–36. Azimuth Selsyn Generator Assembly Mounted on Inner Ring.

(Figure 6-36), at the left of the gunner's head as he looks through the retiflector sight. The purpose of this assembly is to send signal voltages from the sighting station indicating the position of the sight in azimuth. The assembly also provides a tail-bearing mounting for the left-hand side of the yoke assembly by means of which the yoke assembly is pivoted. (Figure 6-38.)

Major Parts

This assembly consists of a one-speed and a 31-speed Selsyn generator, a cast-aluminum-alloy housing to which the Selsyn generators are attached, and a gear train which engages

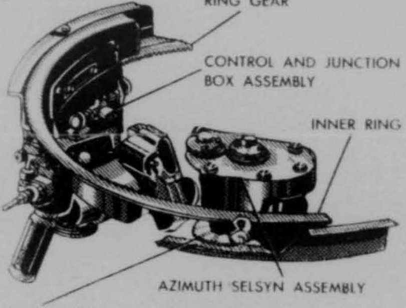

Figure 6–37. Cutaway to Show How Main Drive Gear Engages Internal Gear on Stationary Outer Ring.

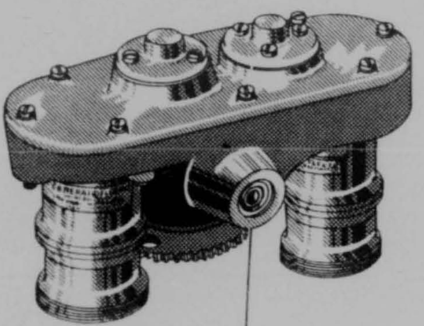

Figure 6–38. Yoke Side of Azimuth Selsyn Generator Assembly.

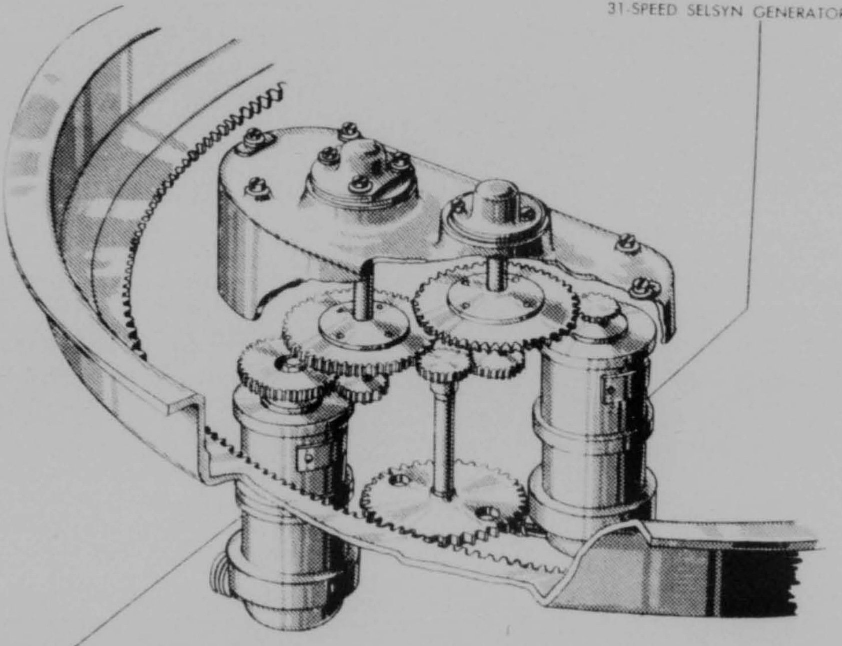

Figure 6–39. Schematic Drawing of Azimuth Selsyn Units Geared to Stationary Outer Ring Gear.

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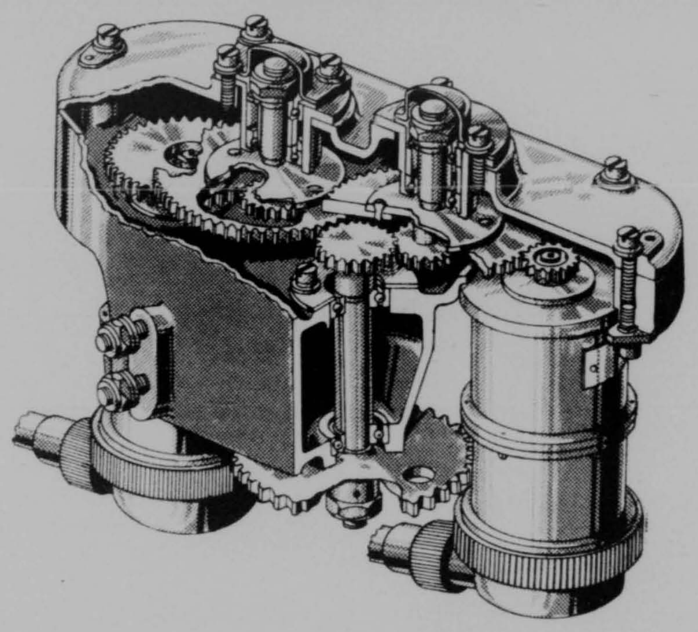

Figure 6—40. Cutaway View of Azimuth Selsyn Units, Showing Gears, Shafts, and Bearings.

the stationary internal gear on the outer ring. The gear train is located within the housing.

Selsyn-generator Units. The mechanical construction and the electrical operation of the Selsyn generators, as well as the reasons for the use of duplicate units are given under this section. Each of the Selsyn generators is mounted vertically on the under-side of the gear housing. The flange of each Selsyn-generator end shield is held in a rabbeted recess of the housing by three clamps. Each clamp is held to the housing by a screw.

Gear Train. In Figure 6-39, the gear train which connects the rotors of the Selsyn generators to the stationary internal gear of the outer ring is shown schematically. The gearing which drives the one-speed generator rotor is shown as part "a" in Figure 6-39 to distinguish it from the gearing, which drives the 31-speed generator rotor, shown as "b" in Figure 6-39. The main drive gear and shaft are common to both. This gearing causes the rotor of the 31-speed generator to turn 31 times faster than the rotor of the one-speed generator as the sight is moved in azimuth.

Housing. Figure 6-40 shows the housing with the Selsyn generators attached. The housing has been cut away to show the internal construction of the entire assembly. In this view, the bearing construction which supports the gearing can be seen. Note how the Selsyn generators are held by the clamps in the rabbeted recess in the housing.

Electrical Connections. Power is brought into the rotor and taken off the stator of each Selsyn generator by means of the cable attached to each Selsyn cap. The cap is held to the Selsyn unit by means of a threaded and flanged collar. Although the caps are shown attached to the Selsyn unit in Figure 6-40, actually the caps are attached to the control unit and junction box by means of the cable and are considered a part of that assembly.

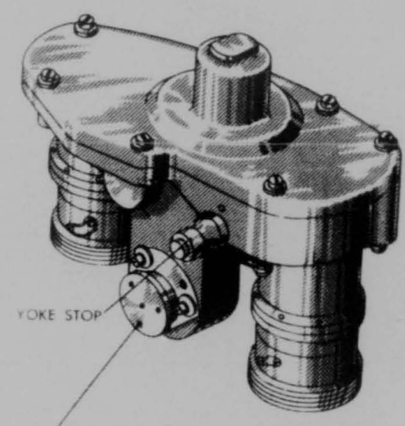

Figure 6—41. Elevation Selsyn Generator Assembly, Yoke Side, Showing Coupling to Yoke and Yoke Stop.

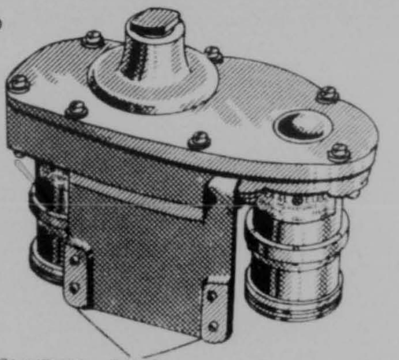

Figure 6—42. Elevation Selsyn Generator Assembly, Showing Mounting Pads.

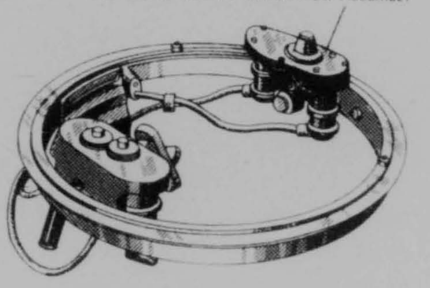

Figure 6—43. Elevation Selsyn Generator Assembly, Mounted on Inner Ring.

6. ELEVATION SELSYN-GENERATOR ASSEMBLY

(Figures 6-41, 6-42 and 6-43.)

Function

The elevation Selsyn-generator assembly is bolted to the inner ring of the sighting station (Figure 6-41), to the right of the gunner's head as he looks into the retiflector sight. The purpose of this assembly is to send signal voltages from the sighting station, indicating the position of the sight in elevation.

Major Parts

This assembly consists of a one-speed and a 31-speed Selsyn generator, a cast-aluminum housing to which the Selsyn generators are attached, and a gear train which connects the rotors of the Selsyns with the yoke of the sighting station.

Selsyn-generator Units. The elevation Selsyn generators are identical to the azimuth Selsyn generators, and are attached to the housing in the same fashion.

Gear Train. In Figure 6-44, the gear train which connects the rotors of the Selsyn generators with the yoke assembly of the sighting station is shown schematically. The gearing which drives the one-speed generator rotor is shown as "a" to distinguish it from the gearing which drives the 31-speed generator rotor, shown as "b". The plate, which attaches to the yoke assembly, and the bevel gearing is common to both 1- and 31-speed gearing. This gearing causes the rotor of the 31-speed generator to turn 31 times faster than the rotor of the one-speed generator as the yoke assembly is moved in elevation.

Housing. Figure 6-45 shows the housing with the Selsyn generators attached. The housing has been cut away to show the internal construction of the entire assembly. The yoke assembly is attached to the plate, and is pivoted at this point. As the yoke is turned, its motion is carried through the gearing to the

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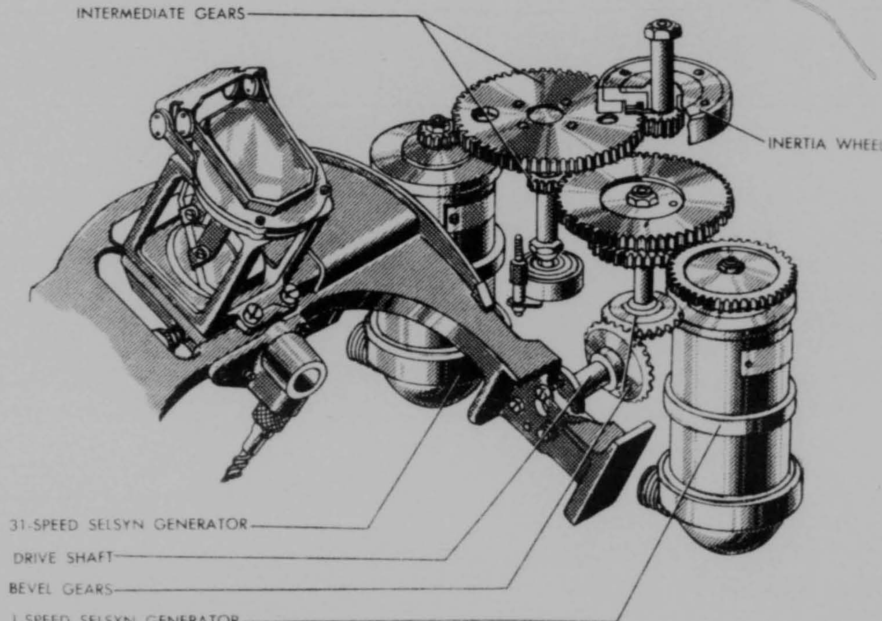

Figure 6–44. Elevation Selsyn Generator Assembly Gearing.

Selsyn generator rotors. This view shows the details of the bearings which support the gears, and the manner in which the Selsyn generators are attached to the housing. The Selsyn generators are held by the clamp in the rabbeted recess in the housing so that the Selsyn units can be "zeroed."

Inertia Wheel. Within the housing, and connected to the gear train is an inertia wheel. This wheel smooths the motion of the sight in elevation through its fly-wheel action. Figures 6-44 and 6-45 show how the inertia wheel is connected to the gearing. Note that this connection is made through a clutch. This is to permit the gunner to slew quickly, to move the sight rapidly when a new target is sighted. During normal use, the inertia wheel helps prevent jumpy tracking.

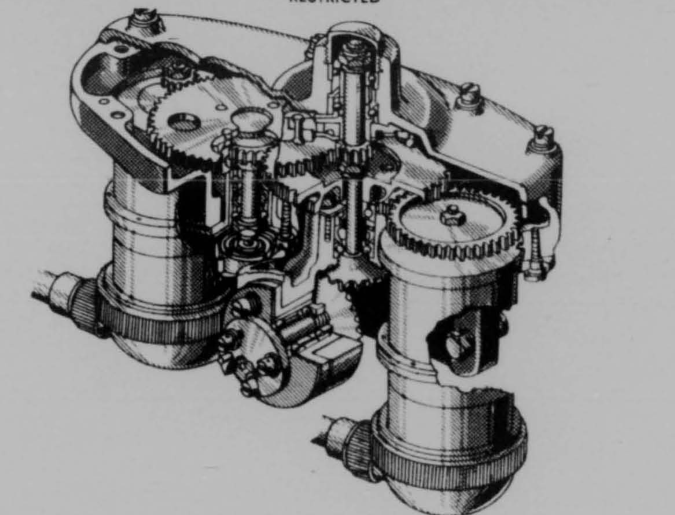

Figure 6–45. Elevation Selsyn Units, Showing Gears, Shafts, and Bearings.

Electrical Connections

Power is brought into the rotor and taken off the stator of each Selsyn generator by means of the cable attached to each Selsyn cap. The cap is held to the Selsyn unit by means of a threaded and flanged collar. Although the caps are shown attached to the Selsyn unit in Figure 6-45, actually the caps are attached to the control unit and junction box by means of the cable and are considered a part of that assembly.

7. YOKE ASSEMBLY

(Figure 6-46.)

It is necessary that the retiflector sight be so mounted as to permit motion in elevation as well as in azimuth. Also, the mounting must not interfere with the gunner's line of sight. These objectives are conveniently accomplished through the use of a yoke-shaped aluminum-alloy casting. The sight is mounted on the center of the closed end of the yoke. The yoke assembly is mounted between the two Selsyn-generator assemblies. (Figure 6-47.) Because the yoke is pivoted at its mounting points, the closed end on which the retiflector sight is mounted is free to move up and down.

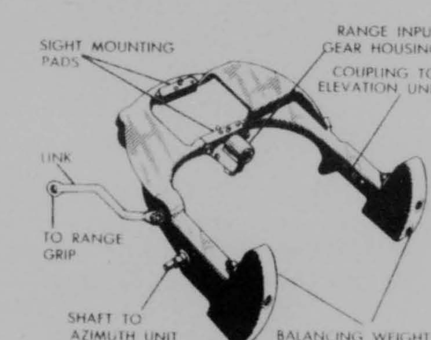

Figure 6–46. Yoke Assembly, Ring Type Sighting Station.

Counterbalancing weights are used at the open end of the yoke.

The yoke is connected to the elevation Selsyn generator assembly as shown in the schematic view in Figure 6-48. As the yoke is moved in elevation, its motion is translated to the Selsyn rotors by the gear train. The manner in which the gunner moves the yoke and thus his sight in elevation, is shown in the

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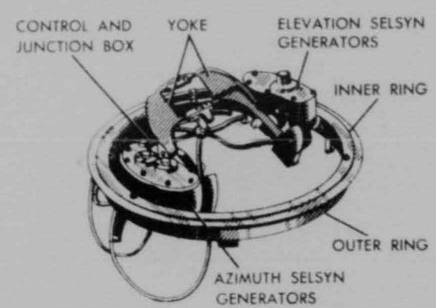

Figure 6—47. Yoke Assembly Mounted on Sighting Station.

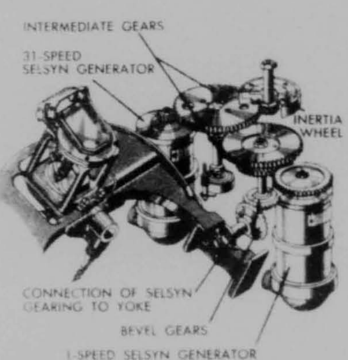

Figure 6—48. Yoke Connected to Elevation Selsyn Generator Assembly.

schematic view in Figure 6-50. Here the control unit and junction box assembly with the gunner's control grips is shown together with the yoke and the mechanical linkage between the control grips and the yoke. The parts concerned with the elevation motion are shown in "a" of Figure 6-50. As the gunner moves the control handles, the yoke is elevated or lowered by means of the mechanical link connected between the yoke and the movable boss on the control unit and junction box assembly. Movement of the control handles moves the boss. The yoke can be moved through 95 degrees from vertical to 5 degrees below the horizontal.

Figure 6-50 also shows how the gunner supplies the retiflector sight with its "range input", and input which when passed on to the computer enables that equipment to compute the range of the target. When the gunner twists the range grip, he controls the diameter of a circle of dots which appear in his sight. This control is effected by the gearing in the range grip and the flexible shafting connected to the sight (shown mounted on the yoke). Parts concerned with range input are shown in "b" in the, diagram. (Figure 6-49.)

One of the single-action gyroscopes (elevation) is mounted on brackets above and parallel to the right-hand arm of the yoke, and the other (azimuth) is mounted on brackets just below and parallel to the right-hand arm of the yoke. The gyros thus move with the yoke assembly as it moves in both azimuth and elevation.

RETIFLECTOR SIGHT MODEL NUMBERS

Bell-Howell Design No. 165 Model	Sighting Station Type	Max. No. of Dots	Range Transmitted	Use
A	Pedestal	9	ac	Sighting Stations 2CSR3B1 through B8 and B12
B	Ring	9	ac	
C	Pedestal	9	ac	
D	Ring	9	ac	
E	Pedestal	18	ac	
F	Ring	18	ac	
G	Pedestal	9	dc	Sighting Station 2CSR3C3
A or C modified d-c range	Pedestal	9	dc	Sighting Station 2CSR3B7 modified for d-c range

Figure 6—49. Retiflector Sight Model Numbers.

Figure 6—50. Schematic Diagram Showing How the Control Grips are Linked to the Yoke, and How the Range Grip is Connected to the Sight.

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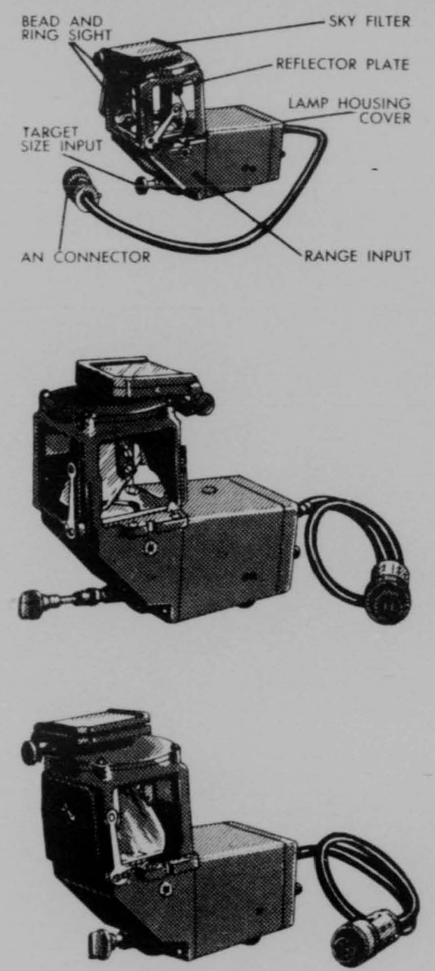

Figure 6–51. (A & B). Retiflector Sight, Models B, C and D or F.

8. RETIFLECTOR SIGHT

The retiflector sights used on all sighting stations are manufactured for the General Electric Company by the Bell and Howell Company. For detailed information on the models used, reference is made to Figure 6-49, 51, 51A, 51B, and 52.

Major Parts

Optical System. Figure 6-51 shows the major parts of the retiflector sight. This is a partially exploded view showing the parts forming the optical system of the sight. These parts are a double-filament reticle lamp which is the light source for the reticle image; a small indicating lamp which lights when the computer is out of the system; a condensing lens; a filter; the reticle assembly, consisting of range-, neutral-, and target-reticle assemblies (which form the reticle image); a 45-degree mirror which turns the formed reticle image upward; a cover plate which encloses the reticle box, but permits passage of light, a reflector plate on which the reticle image appears and through which the gunner looks; and a Magnin mirror which collimates or makes parallel the light rays which form the reticle image.

Sky Filters and Ring-and-bead Fixture. Sky filters are provided to cut down glare and thus increase the brilliancy of the reticle image during daylight flights. The filters are hinged so that they can be swung out of the line of sight during night flights. A ring-and-bead fixture is provided for emergency use.

Electrical Elements. A potentiometer controlled by movement of the range-reticle assembly provides the computer with an electrical signal representing the range of the target. The reticle lamp is built with two independent filaments to guard against burn out. A filament-selector switch to turn on one or the other filament is located on the removable cover of the lamp housing. The intensity of the light from the filament lamp can be varied by turning the reticle-lamp rheostat on the control and junction-box assembly (Figure 6-33).

Operation

Figure 6-53 shows the optical system schematically. In the interest of simplicity, only the center dot and one of the reticle image dots are shown in this diagram. The light from the reticle lamp passes through an orange-colored filter (which gives the reticle image its characteristic color), the condensing lens and through an indicator disk with a circular opening the size of the maximum reticle image.

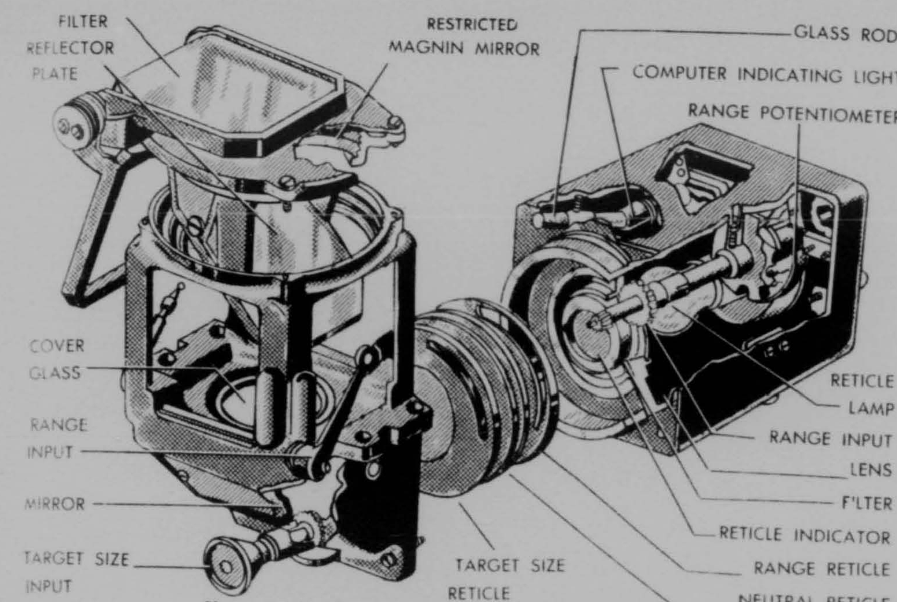

Figure 6–52. Partially Exploded View of Retiflector Sight.

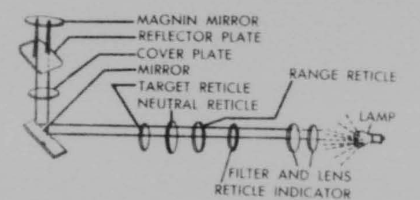

Figure 6–53 Schematic Diagram of Optical System of Retiflector Sight.

This disk serves the same purpose as a mask. However, there is an opening cut into the inside diameter of the disk to permit passage of light through the target size figures.

The light now passes through the reticle assembly where it is broken up into the dots which form the reticle image. In addition, the target size numeral is formed.

The formed reticle image is reflected upward by the 45-degree mirror through the cover plate to the reflector plate. Here about 80 percent of the light passes through the plate to the Magnin mirror. This mirror is so shaped and located, with respect to the reticle

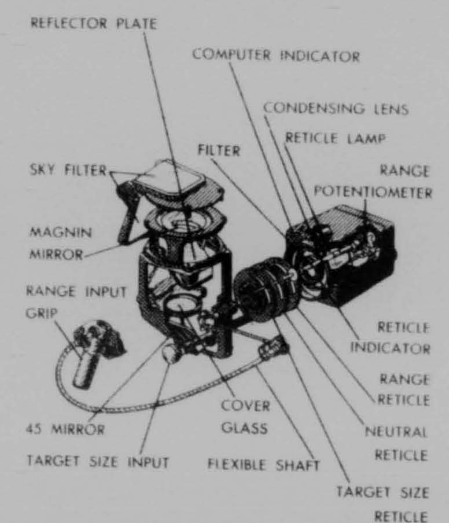

Figure 6–54 Schematic Illustration of Retiflector Sight.

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assembly, that the light rays from the reticle mirror are collimated, or made parallel, and reflected back to the reflector plate. Again, about 80 per cent of the light passes through, and 20 per cent of the light is reflected toward the gunner's eye. These rays form a virtual image of the reticle at infinite distance, or at infinity. Any object in line with the center of this reticle image will appear in the same position, irrespective of the distance of the gunner's eye from the reflector plate. A slight movement of the gunner's eye up or down and from side to side will not change the relative position of target and reticle image. This is one of the chief advantages of the reflecting-type sight as compared with such sights as the ring-and-bead sight.

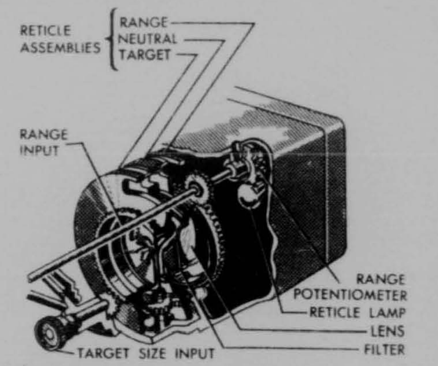

Figure 6—55. Cutaway View of Reticle Assemblies Showing Detail of Gearing Between Reticles.

Reticle Assembly

Figure 6-54, a schematic view of the reti-flector sight, shows the reticle assembly with the three reticles pulled apart, and with the range- and target-size inputs included. The complete reticle assembly consists of a range-reticle assembly, a neutral-reticle assembly, and a target-reticle assembly. The three reticles break down the light from the reticle lamp into a circular pattern of dots which is the reticle image. Each of the reticles is pierced with a series of slots which permit the passage of a portion of the light from the lamp. Thus as the light passes through the reticles, a portion is masked out at each reticle until only the dots forming the reticle image (and the target size numeral) remain. The relationship of each reticle to the others (i.e., each set of slots to the others) is what determines the diameter of the reticle image. As can be seen in Figure 6-55, the slots of the target-reticle assembly are curved. Those of the range reticle are similar, but curve in the opposite direction. The slots of the neutral reticle are straight. Each reticle has a hole in its center to permit the passage of light to form the center dot of one reticle image. The diameter of the reticle image is varied by the gunner when he changes the angular relationship of the three reticles with respect to each other.

The gunner can vary the position of the target-reticle assembly by turning the target-size input knob. In actual practice he sets target size just before aiming at his target and then allows the target reticle to remain in position. The gearing from the target size input knob to the target reticle assembly is shown in Figure 6-54.

The gunner varies the position of the range-reticle assembly by turning the range input grip on the sighting station. The gearing and shafting connections shown translate this motion into a motion of the range reticle.

The neutral-reticle assembly is located between the target-reticle assembly and the range-reticle assembly and is connected to both by differential gearing. Thus when either one or the other of the outside reticle assemblies is moved, the neutral reticle assembly is moved proportionately.

In Figure 6-55, the reticle assembly is cut away, and the detail of the gear arrangement at the reticle assembly is shown. The three reticles are close together, so that their masking action on the light from the filament lamp gives a clear-cut reticle image. The three reticles ride on the inner surface, or circular bore, of the housing. When either of the outer reticles is moved, the teeth cut on the inside surface of their flanges turn the pinion which is held in the neutral reticle, turning the neutral reticle.

When the range-input gearing turns the range reticle, it also turns the slider of the

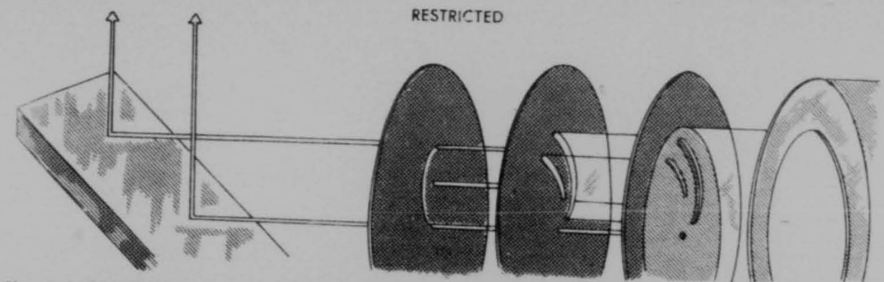

Figure 6—56. Schematic View of Reticles Showing How Sight Dots of Reticle Image Are Formed.

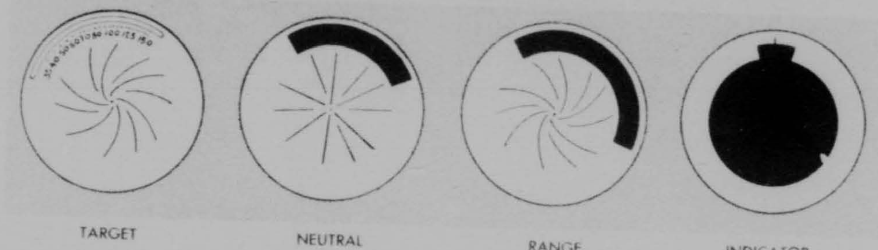

Figure 6—57. Individual Reticles and Reticle Indicator.

potentiometer, which in turn sends the range correction to the computer.

Figure 6-56 shows how the reticles act to mask out portions of the light from the reticle lamp until only the dots forming the reticle image remain. For the sake of illustration, only the center dot and one of the dots in the reticle image circle are shown.

Actually, there are eleven dots forming the reticle image when the diameter of the reticle image circle is large, and five when the diameter is small.

The light from the lamp passes first through the reticle indicator, a disk whose inner diameter is slightly larger than the maximum reticle-image diameter. Then the portion which comes through the center opening falls upon the range reticle. Here all light except that passing through the curved slots and the center dot is blocked. At the neutral reticle the curved segments of light cross the straight reticle slot. Where they cross, light is permitted to pass through. This step forms dots of light. However, more dots are formed than are wanted, thus as these dots fall on the target reticle, only those which intersect a slot in the target reticle get through. In this way the proper dots to form the reticle image are selected. Changing the position of any reticle changes the relationship of the slots and changes the selection of reticle-image dots.

Figure 6-57 shows how the reticles and the reticle indicator are laid out. The keystone-shaped opening in the reticle indicator permits passage of light for the target size indication. The narrow slot above this opening passes light which becomes the index mark on the reflector plate. The wide curved opening in the range and neutral reticles pass the light for the target size indication. The numbers for target size are on the target size reticle.

The short slots on each reticle account for the change from eleven reticle image dots to five when the reticle image is small in diameter.

Figures 6-58 to 6-61 show the inter-relation of the reticle slots of the three disks. The letters represent the slots of the three disks: (a) for the target-size disk, (b) for the neutral disk, and (C) for the range-adjustment disk.

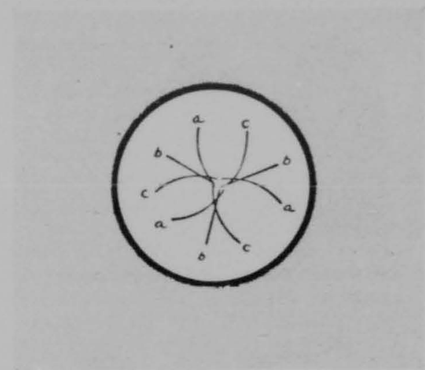

Figure 6—58. 3-Reticle Circle Dots. Target Size Setting 60 Feet.

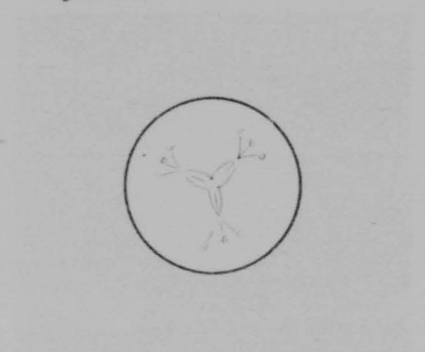

Figure 6—59. 3-Reticle Circle Dots. Target Size Setting 60 Feet.

In order to simplify the drawings, only three intersecting slots have been selected from each of the three disks.

Figure 6-58 shows the manner of intersection where the range disk is set to span a sixty-foot target which is at a considerable distance. In this case the reticle image will be small in diameter, because the slots have common intersection points near the centers of the disks. It should be noted that all three slots must intersect at a common point to permit the passage of light.

Figure 6-59 shows the triple intersection point (where slots of all three disks intersect) at a greater radius from the center, such as would be required to span the same sixty-foot target when much nearer to the sight. Near

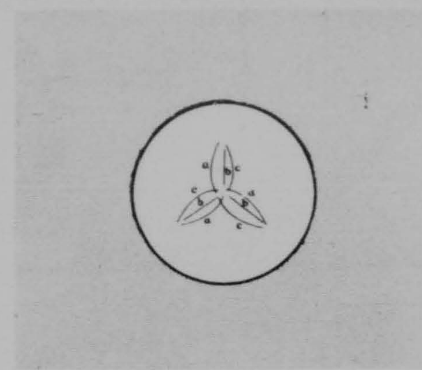

Figure 6—60. 3-Reticle Circle Dots. Target Size Setting 60 Feet.

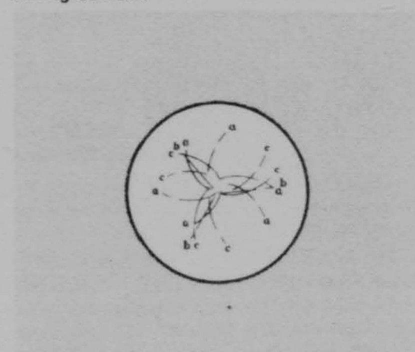

Figure 6—61. 3-Reticle Circle Dots. Target Size Setting 60 Feet.

the center of this drawing are three double intersections from the slots of the target and range disks. These are blanked off by the neutral disk, and consequently no light passes through them.

Figure 6-60 likewise shows the intersections with the range-adjustment disk turned to give the maximum diameter possible such as would be required to span a sixty-foot target quite near the sight.

Figure 6-61 shows adjacent slots at each of the three positions previously used for the target and range disks. It will be noted that a number of double intersections occur, but that the triple intersections are limited to three points on the circumference of a circle which would represent a range setting between those

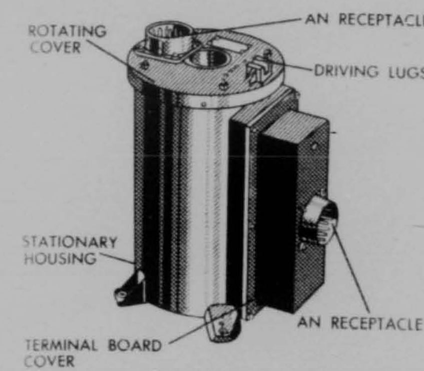

Figure 6—62. Collector Ring Assembly and Junction Box.

of Figure 6-59 and 6-60. This setting most nearly approaches a condition of incorrect indication. If carried out using all slots, it will indicate the reason for using the five short slots shown in each disk, Figure 6-56.

9. COLLECTOR RING ASSEMBLY

This assembly (located under the gunner's seat Figures 6-62 and 6-63) is used to bring in the 33 electrical connections which are required between the ring-type sighting station and the system. A device of this kind is needed in order that the sighting station may remain free to rotate continuously in either direction without limitations of movement or twisting of the control connections. Figure 6-64 shows the exterior of the collector ring assembly designed for such an application.

Operation

When the gunner swings his sight around in the sighting station, he also must swing his seat around somewhat in order to be always sighting forward. In doing this, a mechanical connection from his seat acting on two driving lugs on the top cover of the contact ring assembly (Figure 6-63) rotates the assembly within the housing to a corresponding position. Since the contact rings are complete cylinders, the stationary brushes maintain con-

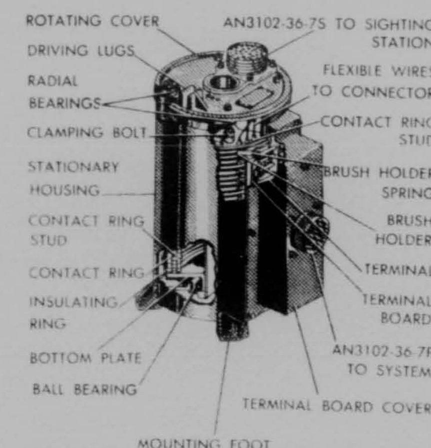

Figure 6—63. Cutaway View of Collector Ring Assembly.

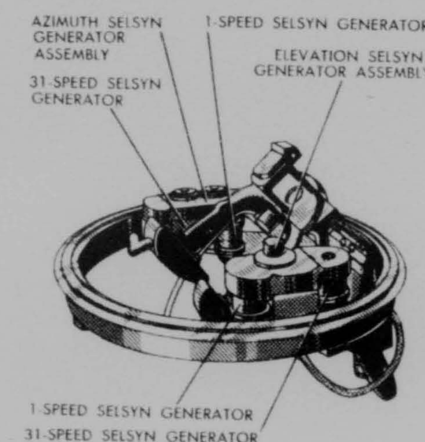

Figure 6—64. Selsyn Generators Mounted on Sighting Station.

tact and continuity of the circuits without limitation on the number or direction of rotations. Likewise, excessive twisting of the connections and limitations of rotation are avoided.

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SECTION III—CONTROL SYSTEM UNIT (SELSYNS)

1. BASIC COMPONENTS

The Selsyn system comprises a Selsyn generator mounted on a sighting station, the generator being electrically connected to a Selsyn control-transformer mounted on the turret. The Selsyn generator is energized by 400-cycle alternating current from the dynamotor. The Selsyn generator, in turn, transmits energy to the Selsyn control-transformer. For this reason, the generator is sometimes referred to as a "Selsyn transmitter." Since the Selsyn control-transformer receives the electrical signal from the generator it is sometimes called a "Selsyn receiver." The Selsyn units make an electrical comparison of the relative positions of the sighting stations and turret. If the sighting station has been moved, the operation of the Selsyn units is such that the Selsyn control-transformer provides a signal which indicates the direction and amount the turret must be moved by the drive motor to bring it back into alignment with the sighting station.

Figure 6—65. Selsyn Generator.

Since both the sighting station and turret move in two different directions, azimuth and elevation, separate Selsyn generators and control-transformers are provided to indicate movement in both these planes. Moreover, in order to provide for accurate alignment of the turret with the sighting station, two sets of Selsyn generators and control-transformers are used in both the azimuth and elevation systems. For example, Figure 6-64 shows four Selsyn generators mounted on a ring sight, two for use with the azimuth Selsyn system and two for use in the elevation system. In the elevation system, one Selsyn generator is geared to rotate once for every revolution of the ring sight and is known as the "1-speed Selsyn generator" while the other is geared to rotate 31 times for every revolution of the sighting station and is known as the "31-speed Selsyn generator." Similarly, the azimuth system is provided with 1- and 31-speed Selsyn generators.

Actually, both the azimuth and elevation Selsyn systems operate in the same manner so that in the following description of the Selsyn generators and control-transformers only one system will be discussed by way of example.

2. SELSYN GENERATOR

As shown by Figure 6-65, a Selsyn generator is a small electrical device which somewhat resembles a motor but which functions similarly to a transformer. Although the Selsyn generator is geared to the sighting station, it is not used to produce a torque to rotate the sighting station. Rather, the purpose of the gear drive is simply to change the position of the Selsyn rotor in accordance with a change in position of the sighting station so that an electrical indication of the position of the sighting station is sent to the control-transformer on the turret.

The Selsyn generator comprises, in general, a stator carrying a three-coil winding, a rotor carrying a single winding which revolves inside the stator, an end-shield forming part of the housing for the elements, and a cap for making electrical connections with the Selsyn. (Figures 6-66 and 6-67.)

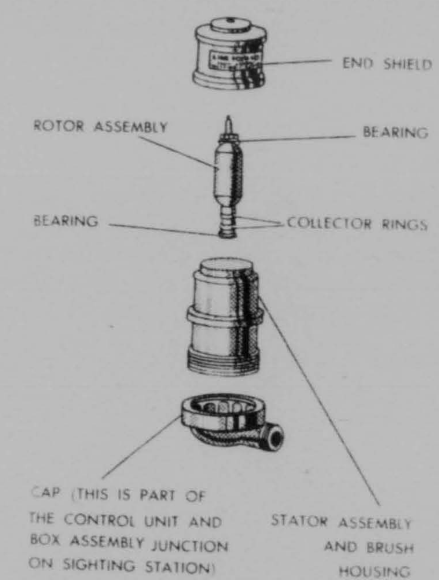

Figure 6—66. Exploded View Selsyn Generator.

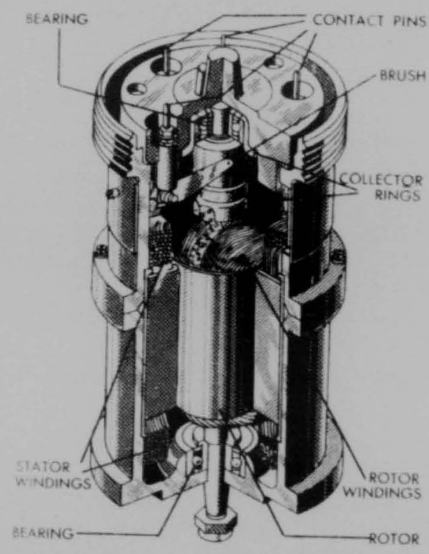

Figure 6—67. Sectional View of Selsyn Generator 2J1F1.

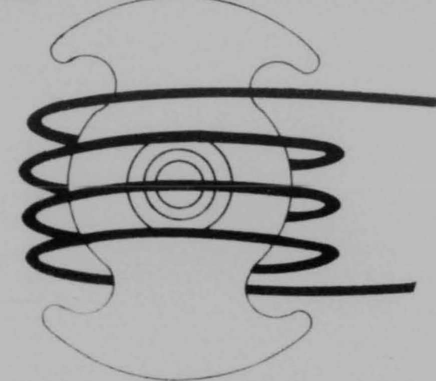

Figure 6—68. Schematic View of Selsyn Generator Rotor.

The stator comprises three windings assembled within a slotted laminated core which is press-fitted into the end-shield. A lead from one end of each of the three windings extends to contact pins carried by the insulated brush holder at the end of the Selsyn. The respective contact pins connected to the stat or windings are identified as "S_1," "S_2," and "S_3." The other ends of the windings are connected together internally in the Selsyn.

The rotor of the Selsyn generator comprises a single coil wound on a laminated iron core. (Figure 6-68.) Opposite ends of the rotor are supported in ball bearings carried by the brush holder and end-shield, respectively. The ends of the rotor winding are brought out to spaced collector rings carried by the rotor shaft. Brushes electrically connected to contact pins carried by the brush holder ride on the collector rings and provide an electrical connection to the rotor. The contact pins connected to the rotor winding are identified as R_1 and R_2 respectively.

The rotor of the Selsyn generator is energized by the 400-cycle alternating current from the dynamotor. This produces a magnetic flux in the rotor winding which, in turn, by transformer action produces a voltage in each of the three windings of the stator. The rotor is geared to the sighting station so that as the sighting station is manually moved, the rotor likewise moves varying the voltage in the stator coils.

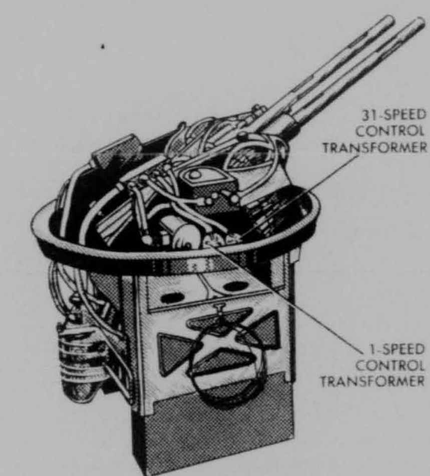

Figure 6–69. Elevation 1 and 31-speed Selsyn Control Transformers Mounted on Turret.

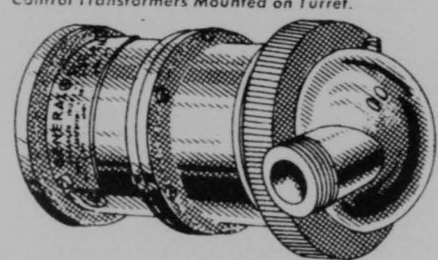

Figure 6–70. Selsyn Control Transformer Model No. 2J1G1.

3. SELSYN CONTROL TRANSFORMER

The turret carries Selsyn control-transformers in number and arrangement corresponding to the Selsyn generators on the sighting station. One- and 31-speed Selsyn control-transformers are provided for both the azimuth and elevation Selsyn systems. (Figure 6-69.)

A Selsyn control-transformer (Figure 6-70) is a small electrical device which, in outward appearance, closely resembles the Selsyn generator. It consists of the same basic elements (Figure 6-71)—stator, rotor, end-shield and connecting cap, which are assembled in the same manner as the Selsyn generator. (Figure 6-67.) Actually, the electrical characteristics of the Selsyn control-transformer differ considerably from those of the Selsyn generator so that these elements are not interchangeable in the system. One of the apparent differences is in the shape of the rotor. The Selsyn control-transformer is provided with a laminated round rotor carrying a single winding (Figure 6-72). Electrical connections to the Selsyn control-transformer are made through contact pins identified R_1, R_2, S_1, S_2, and S_3, the same as for the Selsyn generator.

The three stator windings of the control-transformer are electrically connected to the stator windings in the Selsyn generator so that the voltages appearing in the windings of the Selsyn generator are reproduced in magnitude and polarity in the stator of the Selsyn control-transformer. The resulting

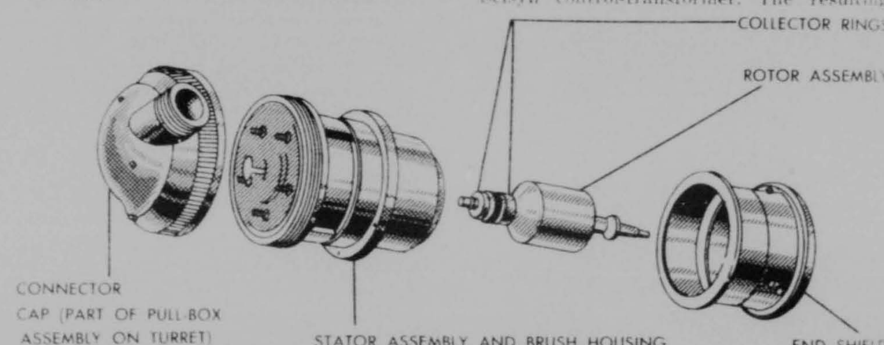

Figure 6–71. Exploded View of Selsyn Control Transformer.

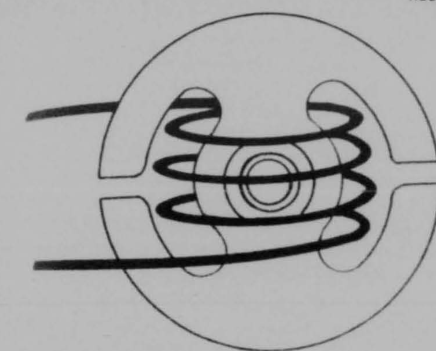

Figure 6–72. Schematic View of Selsyn Control-Transformer Rotor.

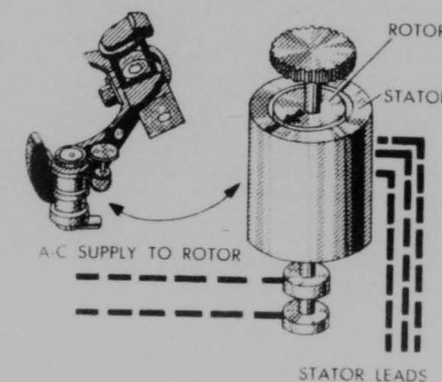

Figure 6–73. Schematic View of Selsyn Generator Geared to Sighting Station.

magnetic flux in the control-transformer stator induces a voltage in the rotor by transformer action which is the signal voltage fed to the servo-amplifier.

4. OPERATION OF SELSYN SYSTEM EXPLAINED IN SCHEMATIC FORM

Figure 6-73 shows a Selsyn generator in schematic outline, geared to a sighting station. The broken lines indicate the 400-cycle alternating current from the dynamotor fed through the collector rings to the rotor of the Selsyn generator. The three broken lines represent the electrical connections from the stator of the Selsyn generator. When the sighting station is moved, the rotor of the Selsyn generator is moved through the gearing. (Figure 6-74.) This causes the rotor to vary the voltage in each of the three stator windings and consequently across the three leads from the stator windings.

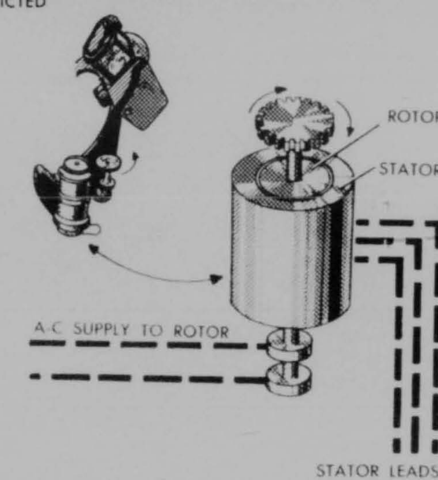

Figure 6–74. Movement of Sighting Station Driving Selsyn-Generator Rotor.

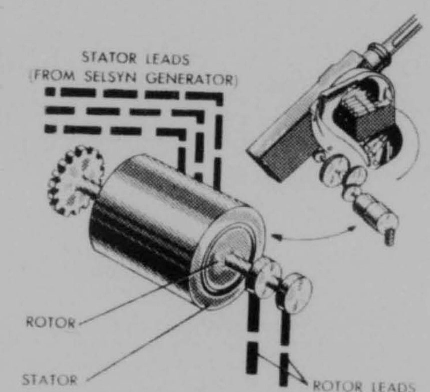

Figure 6–75. Schematic View of Selsyn Control Transformer (Rotor Geared to Turret).

Figure 6-75 shows a Selsyn control-transformer geared to the turret. As the turret moves, the rotor of the Selsyn control-trans-

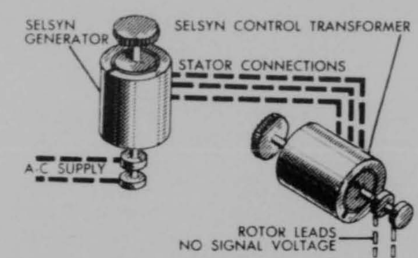

Figure 6—76. Schematic View of Selsyn Generator Connected to Selsyn Control Transformer.

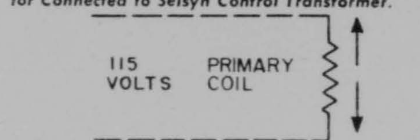

Figure 6—77. Coil Energized with an Alternating Current.

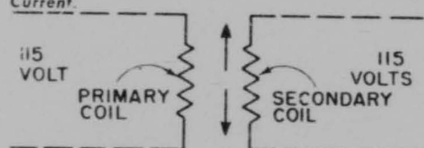

Figure 6—78. Voltage Induced in Secondary Coil from Primary Coil.

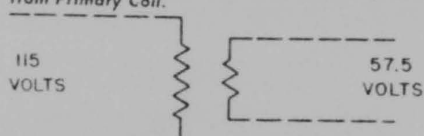

Figure 6—79. Reduced Voltage in Secondary Coil Having Reduced Number of Turns.

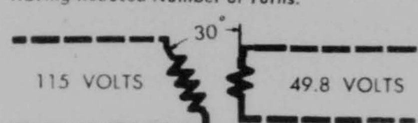

Figure 6—80. Varying Position of Primary Coil to Reduce Voltage in Secondary Coil.

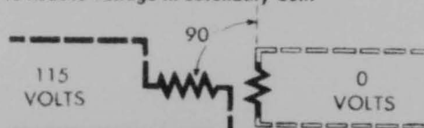

Figure 6—81. Positioning Primary Coil to Reduce Voltage in Secondary Coil to Zero.

former is likewise moved by the gear train. It should be noted that the Selsyn control-transformer does not drive the turret to any particular position; the means for driving the turret is the turret-drive motor. The three broken lines indicate the electrical connections to the stator from the Selsyn generator. The two heavier broken lines indicate the voltage output from the rotor of the Selsyn control-transformer, in the event that sight and guns are out of alignment.

The manner in which the Selsyn generator and control-transformer are connected together is shown in Figure 6-76. The stator windings are shown electrically connected by the broken lines. The Selsyn generator is continuously sending an electrical signal which is representative of the position of the sighting station along the broken lines to the Selsyn control-transformer. The Selsyn control-transformer compares this signal with its own position representing the position of the turret. If the turret is in alignment with the sight, no voltage signal appears at the control-transformer rotor as is indicated by the broken blank lines in Figure 6-76. However, if the turret and sighting station are not in alignment, a voltage signal will appear at the collector rings of the control-transformer rotor. As will appear later, this voltage signal is fed to the servo-amplifier. The manner in which this voltage signal is developed in the Selsyn control-transformer is set forth in the paragraph to follow.

5. ELECTRICAL OPERATION OF SELSYN SYSTEM

When an alternating current is passed through a winding, a magnetic field, or flux, is created around the coil which takes a direction parallel to the coil (Figure 6-77). In the Selsyn system this coil, which corresponds to the rotor of the Selsyn generator, is energized by the 115-volt 400-cycle alternating current derived from the dynamotor.

If another identical coil is brought into the magnetic field of the first coil, a voltage is said to be induced in the second coil. This is known as the transformer action. When the two coils are identical, the voltage induced in the secondary coil will be substantially the

same as that appearing in the primary coil (Figure 6-78). However, if the number of turns in the secondary coil is reduced, for example, to one-half the number of turns in the primary coil, the voltage in the secondary coil will be reduced by one-half and will amount to 57.5 volts (Figure 6-79). This is the maximum voltage induced between the terminals of any two coils in the stator of the Selsyn generator.

Another means of varying the voltage in the secondary coil is to rotate the primary coil relative to the secondary so that the coils are no longer parallel. This will reduce the voltage in the secondary coil and the value of the voltage will depend upon the angle through which the primary coil is moved. The voltage may be determined by multiplying the maximum voltage in the secondary by the trigonometric cosine of the angle (Figure 6-80). When the primary coil is moved through an angle of 30 degrees the voltage induced in the secondary is 49.8 volts.

If the primary coil is rotated to a position at right angles to the secondary coil, then the secondary coil will link none of the magnetic flux of the primary coil so that the voltage in the secondary will drop to zero (Figure 6-81). In this way the voltage in the secondary coil may be varied from a maximum of 57.5 to zero volts by simply turning the primary coil. In a similar way the voltage between the terminals of any two coils of the Selsyn-generator stator is varied from a maximum of 57.5 volts to zero simply by turning the rotor in accordance with movement of the sighting station.

If desired, the secondary coil may be moved with respect to the primary coil with the same result. When this is done the voltage through the secondary coil will vary according to the angular positions of the coil. In Figure 6-82, the secondary coil has been moved at right angles to the primary coil so that zero voltage is induced in it.

The basic principles thus far set forth are utilized in the operation of the Selsyn system. In Figure 6-83, the primary and secondary coils have been associated with the turret and sighting station which are separated from one another by any desired distance, thirty-five in

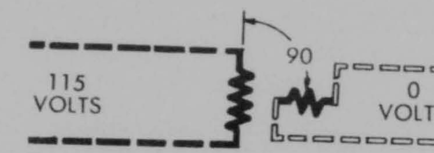

Figure 6—82. Positioning Secondary Coil to Reduce Voltage in Secondary Coil to Zero.

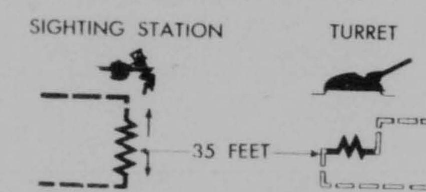

Figure 6—83. Schematic View of Primary and Secondary Coil (Applied to Sighting Station and Turret).

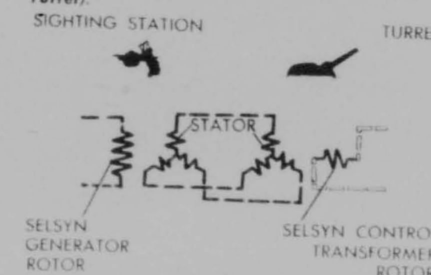

Figure 6—84. Primary Coil (Generator Rotor) and Secondary Coil (Control-Transformer Rotor) Interconnected by Selsyn Stators.

the example given. The primary coil will hereinafter be referred to as the "rotor" of the Selsyn generator mounted on the sight, and the secondary coil as the rotor of the Selsyn control-transformer mounted on the turret. When sight and guns are in alignment, these rotors are electrically at right angles to each other so that no voltage signal is induced in the control-transformer rotor (secondary coil). If the sighting station is moved to rotate the generator rotor so that it is no longer at right angles, a voltage signal would be induced in the control transformer rotor, were it not for the fact that it is thirty-five feet away. Some means must be provided to transmit the position of one rotor to the other. These means are the stators of the Selsyns.

In Figure 6-84, the Selsyn's stators have

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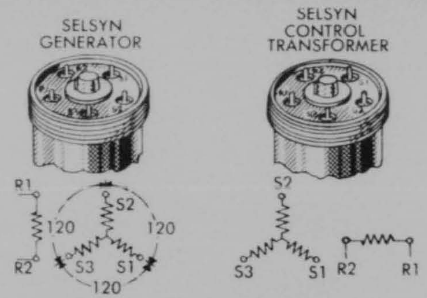

Figure 6—85. Generator and Selsyn Control Transformer with Windings Identified.

been electrically connected together, as indicated by the broken lines. Now if the Selsyn rotor on the sighting station is moved it will vary the voltages between the terminals of the three coils of the stator, and these voltages will appear in the stator of the control-transformer reproducing the flux or magnetic pattern of the generator stator. In this way the position of the generator rotor is transmitted to the rotor of the control transformer.

6. ELECTRICAL SYMBOLS OF SELSYNS

Figure 6-85 illustrates the electrical symbols for a Selsyn generator and Selsyn-control-transformer. In each case the three windings of the stator coils have been indicated as spaced 120 degrees apart and the windings identified as S_1, S_2, and S_3 corresponding to the contact pins of the Selsyns. In the case of the Selsyn generator the rotor winding R_1 and R_2 is shown as perpendicular to a line drawn between terminals S_1 and S_3. In the case of the control transformer the rotor R_1 and R_2 is shown parallel to a line drawn between terminals S_1 and S_3.

The positions of the rotors shown (Figure 6-85) are standard reference symbols used to represent the electrical positions of the Selsyns when the turret and sighting station are in alignment. (Figures 6-84 and 6-85, for comparison.) Moreover the windings on the rotors and stators are always identified with the letters shown and in the positions shown, when the Selsyns are in their electrical reference or zero position. The proper procedures for zeroing the Selsyns is described later.

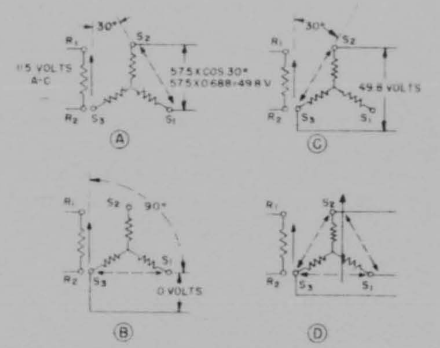

Figure 6—86. Voltages Between Windings of Selsyn Stator with Rotor in Zero Position.

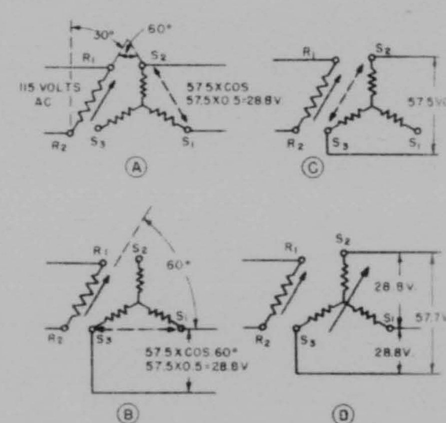

Figure 6—87. Voltages Between Windings of Selsyn with Rotor Moved to 30 Degrees.

It has been stated that as the rotor of the Selsyn generator moves, the voltages in the windings of the stator coils vary to indicate the position of the rotor. Figure 6-86 illustrates the manner in which the voltages in the windings of the Selsyn generator may be computed for the zero position of the rotor. The Selsyn generator is designed so that the maximum voltage obtained between any two windings of the stator is 57.5 volts when 115-volt 400-cycle alternating current is applied to the rotor. This condition is obtained when the rotor is parallel to the magnetic flux path between any two windings or terminals. The flux direction between S_1 and S_2 is shown by the dotted diagonal line between S_1 and S_2 which is the resistant of the magnetic flux in each of the coils. Since the resultant flux between S_1 and S_2 is not parallel to the rotor R_1 and R_2 but at an angle of 30 degrees thereto, the voltage across S_1 and S_2 will not be 57.5 volts but rather

57.5 X cosine 30 degrees
57.5 X .866 = 49.8 volts.

The voltage between S_1 and S_3 is
57.5 X cosine 90 degrees
57.5 X 0 = 0 volts

The voltage between S_3 and S_2 is
57.5 X cosine 30 degrees
57.5 X .866 = 49.8 volts

The resultant of the magnetic flux in all the windings is a net resultant flux in the stator, parallel to the flux in the rotor. The direction of this resultant flux is illustrated by the black arrow in Figure 6-86.

If the generator rotor is now moved clockwise 30 degrees (Figure 6-87), the voltage between the stator terminals will change to move the resultant flux in the stator 30 degrees. This means that the direction of the resultant flux between S_1 and S_2 is now at an angle of 60 degrees to the rotor so that the voltage between S_1 and S_2 is now

57.5 X cosine 50 degrees
57.5 X .5 = 28.8 volts

In a similar way, it will be seen from Figure 6-87 that the voltage between S_2 and S_3 is 28.8 volts. The voltage between S_1 and S_3 is a maximum of 57.5 volts because the direction of the resultant flux between these points is parallel to the direction of the rotor flux so that maximum flux is linked. The result of the flux changes in the stator windings is to move the resultant direction of flux through the stator 30 degrees clockwise parallel to the rotor flux.

In this way, the direction of resultant flux in the stator follows movement of the rotor in either direction. If now the flux direction in the generator stator is transferred to the stator of the Selsyn control-transformer, the rotor of the control-transformer will now be the position of the generator rotor.

7. ELECTRICAL CONNECTIONS BETWEEN SELSYN GENERATORS AND SELSYN CONTROL-TRANSFORMERS

The stators of the Selsyn generator and control-transformer are shown electrically connected. When the generator rotor is energized with 115-volt 400-cycle alternating current, voltages in both the stator windings are the same and the direction of the resultant magnetic flux in both stators will be the same as indicated by the arrows. The direction of flux in the control-transformer stator is at right angles to the rotor so that no voltage signal appears across the rotor terminals R_1 and R_2. This means that the turrent and sighting station are in alignment because the system is set up and the Selsyns zeroed with their rotors in the electrical position.

8. HOW THE SELSYN SIGNAL VARIES IN MAGNITUDE WITH AMOUNT OF SIGHT MOVEMENT

If the sighting station is moved so that the rotor of the Selsyn generator moves clockwise 30 degrees, the direction of flux in the control-transformer stator is likewise moved 30 degrees. This means that a portion of the control-transformer stator-flux links with the control-transformer rotor so that a voltage appears across the rotor terminals R_1 and R_2. Due to the characteristics of the control-transformer rotor, the maximum voltage output signal is aproximately 57.5 volts which occurs when the direction of flux in the stator is parallel to the rotor. (When the direction of flux is at right angles the voltage output in the rotor is zero.) However, since the flux direction is at an angle of 60 degrees to the rotor, the voltage output signal of the control-

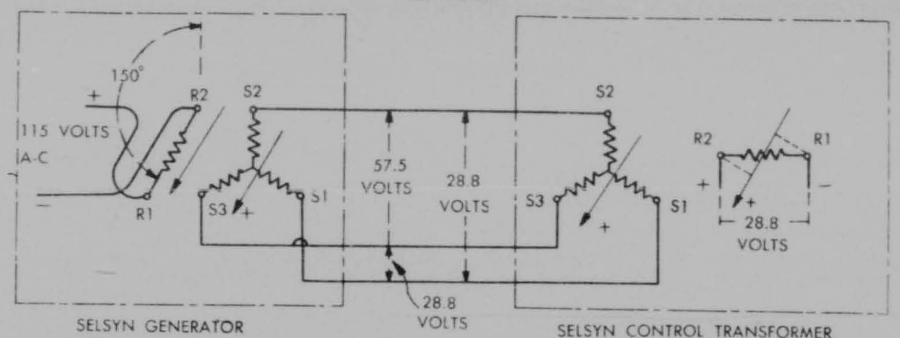

Figure 6—88. How Counterclockwise Movement of Generator Rotor Affects Magnitude and Polarity of Voltage in Control-transformer Rotor.

transformer rotor will amount to

57.5 volts X cosine 60 degrees
57.5 X .5 = 28.8 volts

In this way it will be seen that the magnitude of the voltage-output signal of the Selsyn control-transformer varies directly with the magnitude of the angle through which the sighting station has been rotated. This voltage signal is varied because the rotor of the Selsyn generator on the sighting station is rotated to change the voltage in the Selsyn stators whenever the sighting station is moved.

9. HOW THE POLARITY OF THE SELSYN SIGNAL CHANGES WITH THE DIRECTION OF SIGHT MOVEMENT

The signal voltage from the control-transformer must not only be capable of determining the amount of sight movement, it must also give an indication of the direction of movement. This is accomplished by changing the polarity of the signal voltage in accordance with the direction of movement.

The 400-cycle alternating current has been stopped at that instant on the portion of the cycle when terminal R_1 of the rotor is positive (+) and terminal R_2 negative (—). At this same instant the magnetic flux bath, represented by the directional arrow, will have a + polarity opposite the + end of the rotor. The polarity of the flux represented by the directional arrow will be duplicated in both Selsyn stators and also link the control-transformer rotor. As the + end of the arrow is nearest terminal R_1 of the control-transformer rotor, this terminal R_1 will have a + polarity. (The polarity of R_1 and R_2 may also be determined by projecting a line from the terminals at right angles to the flux directional vector and determining which projected line is nearer the + end of the arrow.) For a 30-degree clockwise rotation of the generator rotor the voltage signal from the control-transformer is 28.8 volts with terminal R_1 of + polarity.

In Figure 6-88 the generator rotor has been rotated 150 degrees counterclockwise by moving the sighting station. This position brings the generator rotor parallel to the position when it was rotated 30 degrees clockwise. This means that the voltages appearing in the stator windings are the same so that the voltage signal from the control-transformer rotor is the same. Although for both positions of the generator rotor, the output signal is 28.8 volts, the Selsyn system distinguishes between the two positions by changing the polarity of the signal. Assuming the alternating current stopped at the same portion of the cycle when terminal R_1 of the generator rotor is positive (+), then when the rotor is moved to the 150-degree position, the + end of the flux direction arrow will be pointed in the opposite direction in Figure 6-88, from that shown by Figure 6-87 because the + end is opposite the + terminal R_1 of the generator rotor. However, the + end of the flux directional arrow is now near-

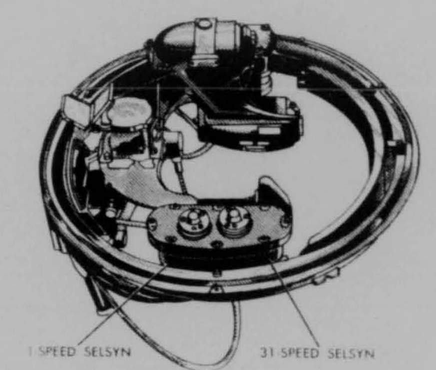

Figure 6—89. Location of 1 and 31-speed Selsyn Generators on Sighting Station.

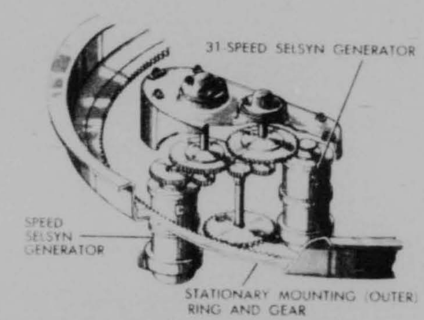

Figure 6—90. Schematic View of Selsyn Gearing on Sighting Station.

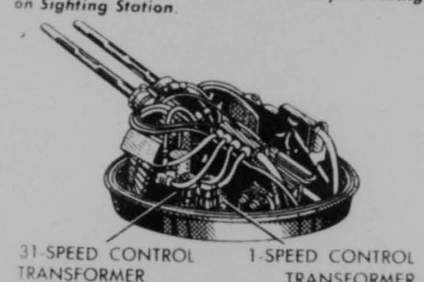

Figure 6—91. Location of 1 and 31-speed Selsyn Control Transformers on Turret.

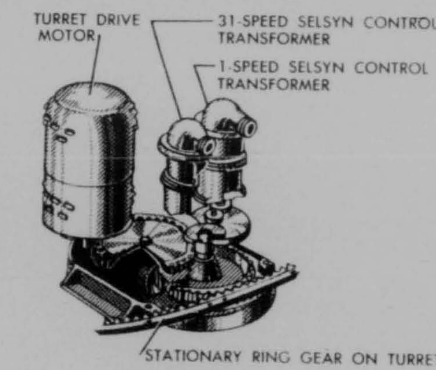

Figure 6—92. Schematic View of Selsyn Gear Train on Turret.

est the R_2, terminal of the control-transformer rotor so that R_2 is positive (+). Thus the polarity of the voltage signal output from the control-transformer varies depending upon the direction of movement of the sighting station even though in certain instances the magnitude of the voltage may be the same.

10. 1- AND 31-SPEED SELSYN SYSTEM

Selsyn generators and control-transformers are subject to small electrical errors due to manufacturing tolerances. Since the turret system must be extremely accurate, certain of the Selsyn units are geared to rotate at speeds higher than those of the turret or sighting stations. Figure 6-89 shows the sighting station with a Selsyn generator mounted thereon to rotate 31 times for every revolution of the sight. The gear train for driving the Selsyn generator is shown by Figure 6-90. If an error of one-half degree occurred in the Selsyn system the actual error at the turret would be 1/62 degree due to the reduction gearing. In addition to the 31-speed Selsyn generator, the system includes a 1-speed Selsyn generator. Figures 6-89 and 6-90, also show a Selsyn generator mounted on the sighting station and geared to rotate once for each revolution of the sight.

In a similar manner the turret is provided with 1- and 31-speed Selsyn control-transformer, Figure 6-91. These control-trans-

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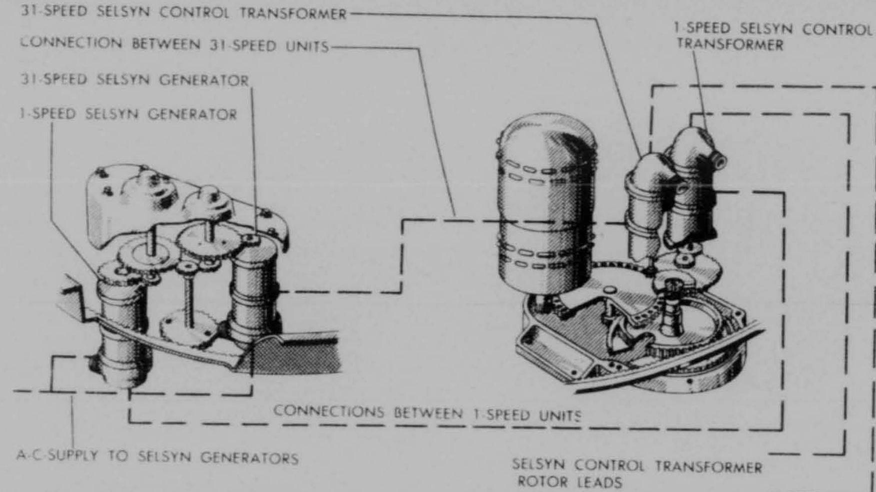

Figure 6–93. Schematic View of Electrical Connections Between 1 and 31-speed Selsyns on Sighting Station and Turret.

formers are driven through the gear train illustrated by Figure 6-92. It should be noted that 1- and 31-speed Selsyn units are used in both the azimuth and elevation Selsyn systems. This means that the sighting station carries a total of four Selsyn generators and the turret four Selsyn control-transformers.

The manner in which the 1- and 31-speed Selsyn units on the sighting station and turret are interconnected is illustrated schematically by Figure 6-93. The corresponding 1- and 31-speed Selsyn stators are electrically connected, as indicated by the broken lines. Both the 1- and 31-speed Selsyn generators on the sighting station are energized by 115-volt 400-cycle alternating current from the dynamotor. Separate 1- and 31-speed Selsyn signal output voltages are obtained from both the 1- and 31-speed Selsyn control-transformers. Both the 1- and 31-speed signals are fed to the servo-amplifiers which selects the signal to be used. If the turret is out of alignment with the sight by more than approximately three degrees the 1-speed Selsyn signal will control the turret through the servo-amplifier. Within three degrees of correspondence the 31-speed signal has control.

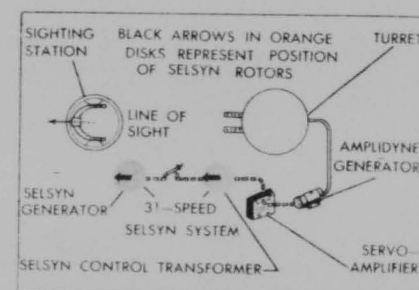

Figure 6–94. Schematic Representation of 31-speed Selsyn Units in Alignment.

11. WHAT HAPPENS WHEN ONLY THE 31-SPEED SELSYN SYSTEM IS USED

In Figure 6-94, a sighting station and turret have been illustrated in schematic outline together with a controlling 31-speed Selsyn system, servo-amplifier and amplidyne. The Selsyn generator and control-transformer are represented by shaded disks. The electrical connection between them is opened or closed by a knifeblade switch. In Figure 6-98 the turret and sighting station are in alignment.

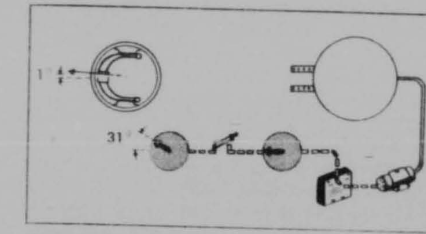

Figure 6–95. Rotation of 31-speed Selsyn Generator When Sighting Station is Moved One Degree.

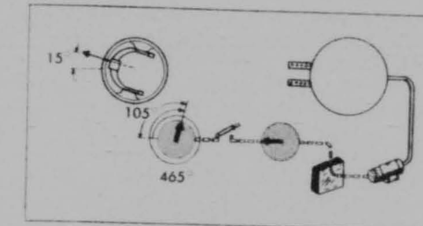

Figure 6–96. Rotation of 31-speed Selsyn Generator When Sighting Station is Moved 15 Degrees.

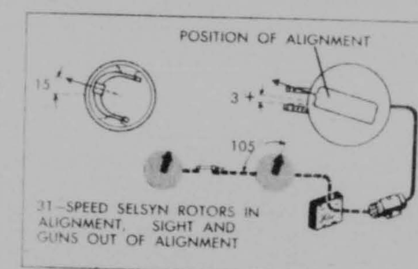

Figure 6–97. Movement of Turret When Electrical Connection Between 31-speed Selsyn Units is Closed.

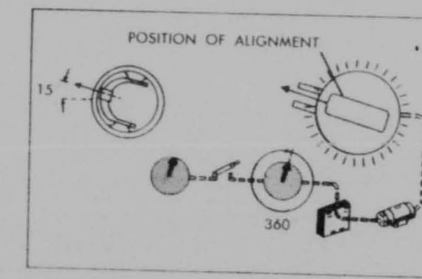

Figure 6–98. Movement of 31-speed Selsyn Control-transformer Rotor When Gun is Moved into Alignment with Sight.

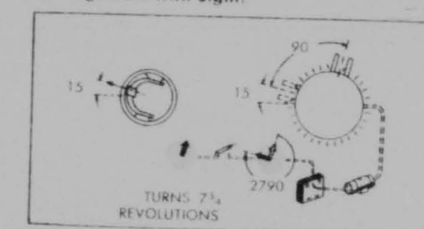

Figure 6–99. Movement of 31-speed Selsyn Control-transformer When Turret is Moved 90 Degrees out of Alignment with Sighting Station.

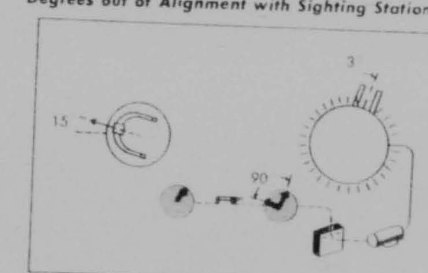

Figure 6–100. Movement of Turret Further out of Alignment When Electrical Connection Between 31-speed Selsyn Units is Closed.

In Figure 6-95 the sighting station has been moved one degree which rotates the 31-speed Selsyn generator 31 degrees. Since the switch is open, no signal is sent to the Selsyn control-transformer and the turret does not move. Figure 6-96 shows the position of the Selsyn generator when the sighting station has been moved 15 degrees. It will be seen that the Selsyn generator has moved one complete revolution of 360 degrees plus an additional 105 degrees. If the switch in the Selsyn system circuit is then closed the turret will be moved to drive the Selsyn control transformer into alignment with the Selsyn generator, or 105 degrees. (Figure 6-97). However, it is apparent that since the Selsyn control-transformer rotates 31 times for each revolution of the turret, the turret moves only approximately three degrees $\left(\frac{105}{31} = 3\right)$ to bring the

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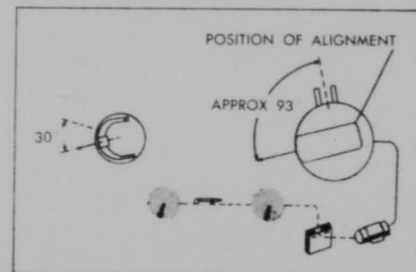

Figure 6—101. Turret Following Movement of Sighting Station but out of Alignment.

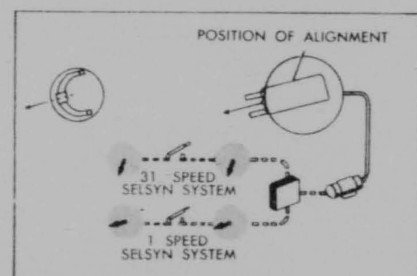

Figure 6—102. Schematic View of Both 1 and 31-speed Selsyn Systems.

Selsyn rotors into alignment. Thus with only the 31-speed Selsyn system operating it is possible for the Selsyn rotors to be in alignment electrically, at the same time that the turret and sighting station are out of alignment.

In Figure 6-98 the switch has been opened and the turret manually moved into alignment with the sighting station. Since the Selsyn rotors revolve 31 times for each revolution of the sight and turret, there are 31 points at which the Selsyn rotors in the system will be in alignment, but only one point where the turret and sight are in alignment. The 31 points at which the Selsyn rotors will line up are indicated by the lines radiating from the turret. It will be seen that one of the disadvantages of using only the accurate 31-speed Selsyn system is that the Selsyn rotors may be in alignment when the sight and turret are out of alignment.

In Figure 6-99 the turret guns have been moved manually 90 degrees out of alignment, with the switch in the Selsyn circuit open. This moves the Selsyn control-transformer 2790 degrees or $7\frac{3}{4}$ revolutions from the position shown by the dotted arrow to that shown by the black arrow. If the switch is now closed it will be found that the Selsyn control transformer will be driven 90 degrees by the turret into correspondence with the Selsyn generator but that at the same time the turret will be moved approximately three degrees farther out of alignment as indicated in Figure 6-100. The Selsyn system is now in alignment but the turret and sight are approximately 98 degrees out of alignment. If the sighting station is moved slowly, it will be found that the Selsyn rotors will rotate in alignment but that the turret and sight will remain 93 degrees out of alignment (Figure 6-101). Thus with a 31-speed Selsyn system only, it is possible to track a target with the turrets and sighting station out of alignment. The above mentioned difficulties encountered in using a 31-speed Selsyn system only, are overcome by the use of a 1-speed Selsyn system.

12. HOW THE 1-SPEED SELSYN SYSTEM ASSISTS THE 31-SPEED SYSTEM

In Figure 6-102 a 1-speed Selsyn system has been added to the Selsyn control and is indicated schematically by the shaded disks. A switch controls the 1-speed system. Also the guns have been manually moved into alignment with the sighting station so that both the 1- and 31-speed Selsyn systems are in alignment.

With both switches open the turret is manually moved 90 degrees out of alignment with the sighting station. As shown by Figure 6-103 the 31-speed Selsyn control-transformer will be rotated 2790 degrees and the 1-speed control-transformer 90 degrees so that both Selsyn control-transformers are out of alignment with their respective Selsyn generators. Now if the switches are closed it will be found that the servo-amplifier selects the 1-speed Selsyn system to take control and drive the turret to within about three degrees of alignment (Figure 6-104). With the 1-speed system there is only one position of alignment between the Selsyn units, and correspondingly only a single position of alignment between the turret and sighting station. After the turret and sighting station have been brought almost into alignment the servo-amplifier transfers control to the 31-speed Selsyn system (Figure 6-105) to bring the turret and sight accurately into alignment.

The 1-speed Selsyn system eliminates the possibility of the turret and sight lining up on any one of the 31 positions of correspondence which exist between the Selsyns in the 31-speed system except the one in which the sight and guns are also in alignment. Actually, the speed of response of the turret to movements of the sighting station is so fast that usually the turret and sight are within three degrees of alignment during normal tracking speeds so that the 31-speed Selsyn system only is used. The 1-speed system is brought into operation when the sight is moved quickly as when "slewing" the turret into position.

13. DYNAMOTOR

The aircraft dynamotor is a combination motor-generator with a common magnetic field and a two-winding armature (rotor assembly). It converts the 27-volt direct-current input into a 115-volt, 400-cycle, alternating-current output. Four units produce the 400-cycle power needed by the Selsyn generators and control-transformer and the servo-amplifiers of the system. The four dynamotors are allotted to the upper, nose, right-and-left-blister, and tail sighting stations respectively.

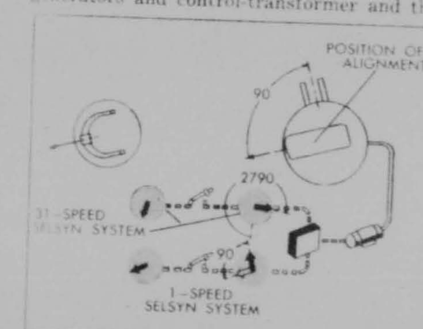

Figure 6—103. Movement of 1 and 31-speed Selsyn Systems.

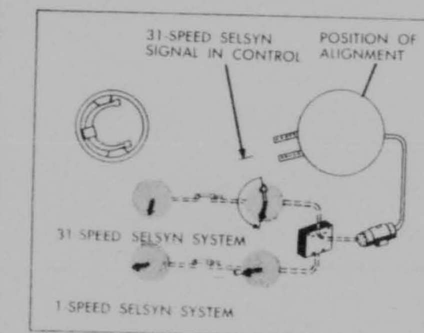

Figure 6—104. Schematic View of Both 1 and 31-speed Selsyn Systems.

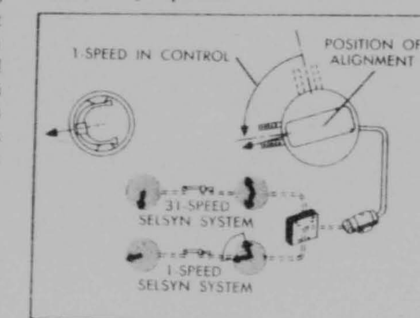

Figure 6—105. Movement of 1 and 31-speed Selsyn Systems

Rating

For complete data on the dynamotor, reference is made either to the dynamotor nameplate or to following information.

INPUT (motor)	
Volts, direct-current	28
Amperes, direct-current	35
OUTPUT (generators)	
Volts, alternating-current	115
Amperes, alternating-current	4.2
Phases	1
Cycles	400
Speed, rpm	8000

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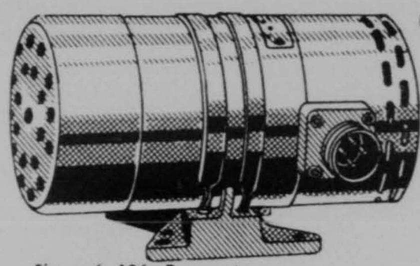

Figure 6—106. Dynamotor.

Component Parts

(Figures 6-106, 107, 108 and 109.) The dynamotor consists of a stator assembly, end covers, a rotor assembly, two brush riggings, a fan, and an AN connector.

Stator Assembly. The stator assembly consists of a steel shell, a yoke which is pressed into the shell, six pole pieces which are bolted to the field yoke, and six series-connected shunt windings. The complete assembly is strapped and bolted to a cast-aluminum base.

End Covers. The ends of the stator assembly are protected against damage by two sheet-aluminum covers. The commutator-end cover, with round ventilating holes in the end, is attached to the commutator-end shield. The collector-end cover is supported by the stator shell.

Rotor Assembly. The rotor assembly consisting of two balancing disks, armature core, armature windings, commutator, collector, and shaft is supported by the commutator-and-collector-end bearings. The bearings are supported by the commutator-end end shield and the collector-end end shield. Four clamp studs fasten the two end shields to the stator assembly. To complete the rotor assembly, the shaft is threaded and machined on the collector end to provide for the mounting of a nut, lock washer, fan, key, shim washers, and spring washer.

Brush Riggings. (Figure 6-110.) The commutator-end brush rigging is supported by the commutator-end end shield and consists of a circular brush yoke which can be shifted for the proper brush position, four spring-supported brush holders, and four brushes. The rigging is connected to pin B in the connector and to the stator assembly. The collector-end brush rigging, supported by the collector-end end shield, consists of a circular brush yoke, two brush spring-supported holders, and two brushes. The rigging is connected to pins A and C in the connector.

Fan. A fan is mounted on the rotor shaft at the AC end of the dynamotor, between the brush rigging and the end cover.

Connector, Capacitor and Resistor. An AN connector to provide a means for quickly connecting and disconnecting the dynamotor, a capacitor to reduce radio interference, and a resistor to add additional resistance in the

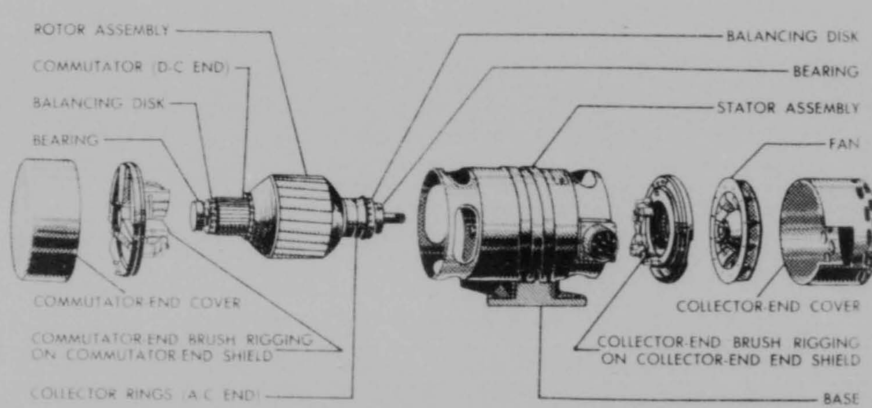

Figure 6—107. Dynamotor, with Major Parts Exploded.

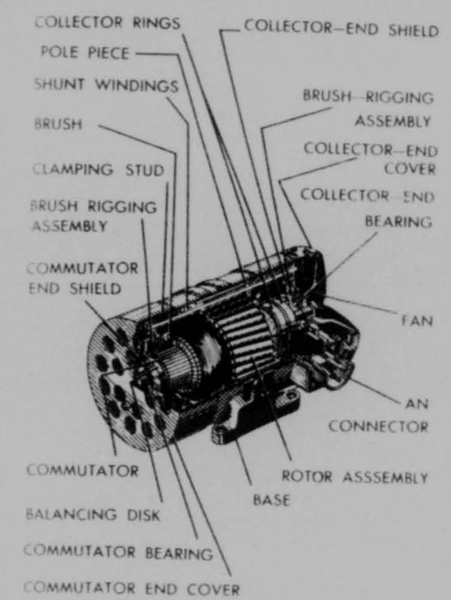

Figure 6—108. Dynamotor, Three Quarter View.

motor circuit complete the assembly. The capacitor is located on the commutator brush-rigging assembly; the resistor is located on the collector brush-rigging assembly.

14. OPERATION

(Figure 6-111.) An understanding of the dynamotor can be obtained from the schematic view of the rotor and field winding. In this view the direct-current input is represented as solid line and the alternating-current output is represented as broken line. Note that this view shows schematically the commutator-end (DC) brushes, the commutator, the field winding, the AC and DC windings of the rotor, the collector rings, and the collector-end (AC) brushes.

The dynamotor is really a DC motor and an AC generator with two sets of armature windings revolving in a common field. Power comes to the dynamotor from the 28-volt airplane system and energizes the field windings and the DC armature windings. Since all electric motors operate on the condition that a conductor (armature windings) carrying an electric current through a magnetic

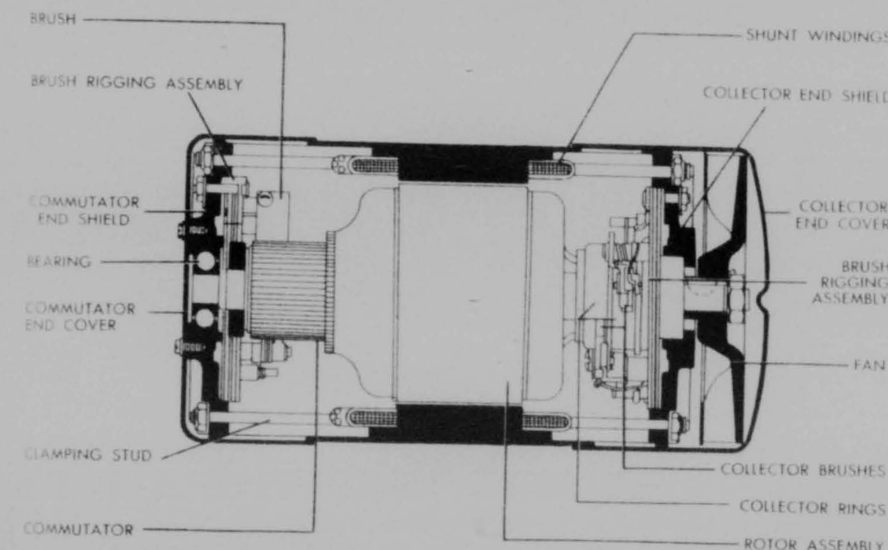

Figure 6—109. Dynamotor, Cross Section View.

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Figure 6—110. Dynamotor Brush-Rigging Assemblies Mounted on End Shields.

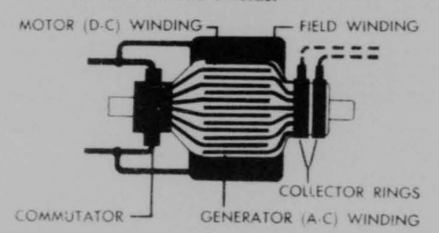

Figure 6—111. Dynamotor Schematic View

field (produced by the field winding) tends to move at right angles to the field, the "motor windings" of the dynamotor convert electrical energy into mechanical energy, causing the armature to rotate. Because the AC armature windings are also on the same armature, they are rotated as well.

The motor of the dynamotor is compound-wound, combining series and shunt characteristics. This is to provide quick starting and a reasonably constant speed while running. The series field winding has only a single turn; voltage drop across the winding is less than 0.5 volt. Thus the shunt field winding is connected across a 26.5 volt line, and current in the shunt winding and the resultant magnetic field is practically constant. The strength of the field being constant, makes the speed practically constant over a wide range of load.

The AC armature windings, revolving in the magnetic field, generate 400 cycles, 115 volt alternating current power. It is true that all electric generators operate on the principle

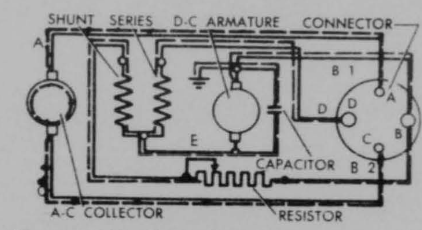

Figure 6—112. Connection Diagram for Dynamotor.

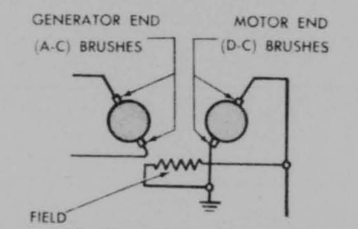

Figure 6—113. Electrical Symbol for Dynamotor.

that an armature conductor moved across a magnetic field generates a voltage. Thus as the AC (generator) windings are rotated in the magnetic field, they generate alternating current, which is taken off by the collector-end brushes. Since no electrical connection is made between the DC (motor) windings and the AC (generator) windings on the rotor, the generated voltage is proportional to the speed (practically constant) and the field strength (practically constant). The generated frequency is also exactly proportional to the speed. To sum up, two characteristics mark the dynamotor:

A generated voltage that is proportional to the input voltage and

A generated frequency that is fairly constant.

Dynamotor Connections

(Figures 6-112 and 6-113). Power is brought to the dynamotor through the AN connector. The diagram (Figure 6-112) shows the dynamotor connections.

SECTION IV—TURRET DRIVE MOTOR AND TWO GUN TURRETS

1. AMPLIDYNE MOTOR-GENERATOR

Upper-forward, Lower-forward, Upper-rear, and Lower-rear Turrets

An amplidyne motor-generator (often called the "amplidyne") is simply a special type of motor-generator set. In a conventional motor-generator, a motor driven by one type of electricity, drives a generator which generates a different type of current from that originally supplied to the motor. The amplidyne motor-generator used in the central-station fire-control system has the motor and the generator mounted in a single housing. The motor, driven by the direct-current supply from the airplane, drives the rotor of the generator. This amplidyne is a direct-current generator which amplifies, or multiplies the less-than-one-watt input to its control field (generator stator) into the more-than-500 watt output of its armature (generator rotor). The energy for this tremendous increase between input and output is obtained from the mechanical energy of the generator rotor, which is driven by the motor.

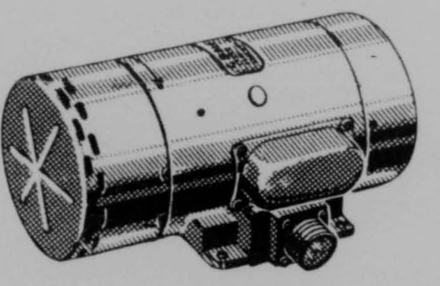

Figure 6—115. Eight Amplidyne Motor-Generator.

Rating

There is complete data on the eight amplidyne motor-generators (Figure 6-115) used in the azimuth and elevation control circuits for the upper-forward turret, lower-forward turret, upper-rear turret, and lower-rear turret. (Reference should be made either to the amplidyne nameplate or the following information.)

INPUT (MOTOR)	
Volts, direct-current	27
Amperes, direct-current	44
OUTPUT (GENERATOR)	
Volts, direct-current	60
Amperes, direct-current	8.8
Watts	530
Speed, rpm.	8300

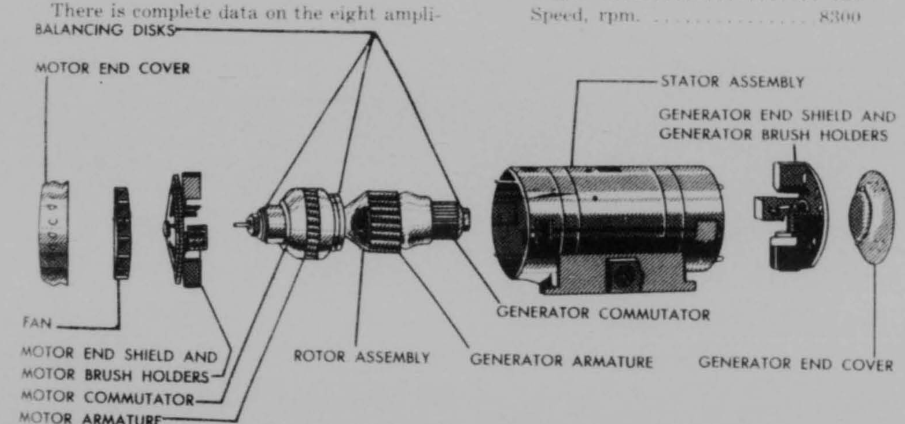

Figure 6—116. Amplidyne Motor-Generator with Major Parts Exploded.

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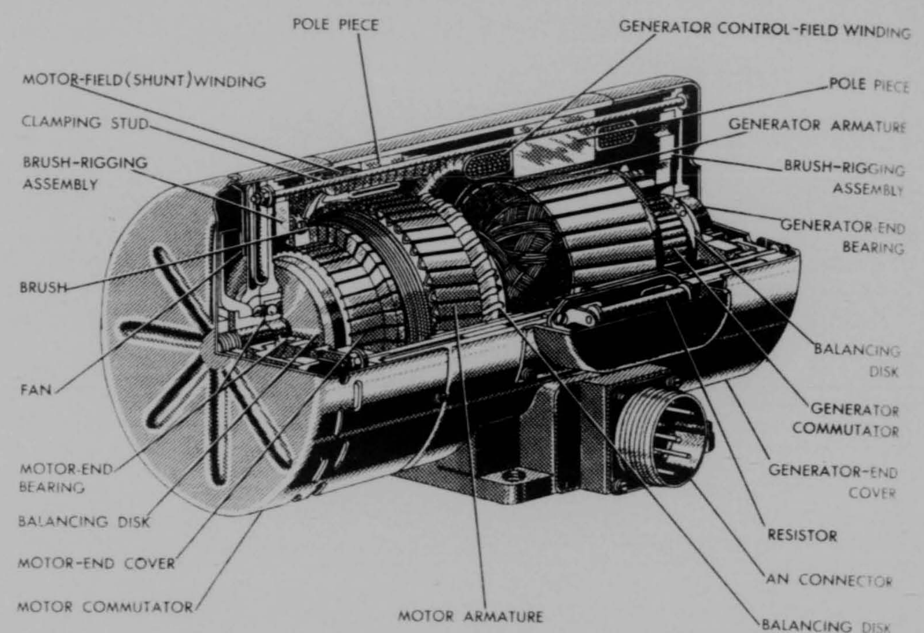

Figure 6—117 Amplidyne Motor-Generator, Three Quarter View.

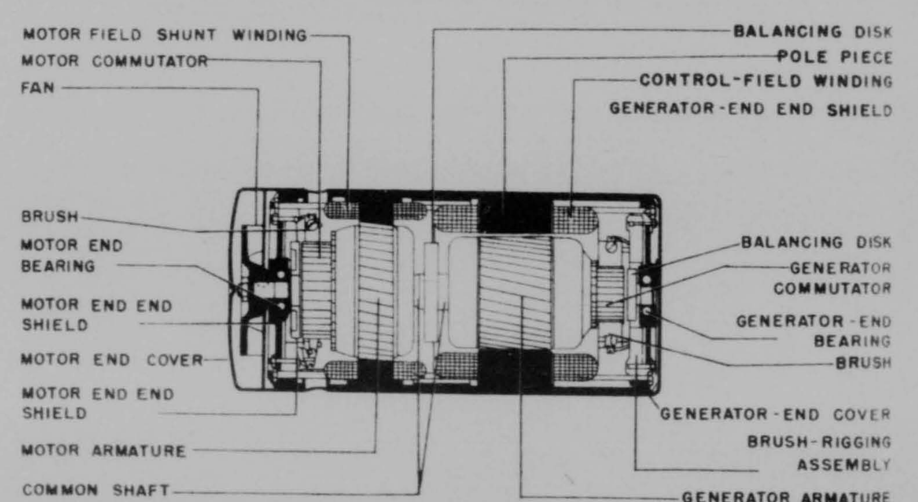

Figure 6—118. Amplidyne Motor-Generator, Cross Section View.

Component Parts

(Figures 6-116, 117 and 118.) The amplidyne motor-generator consists of a stator assembly; a rotor assembly; a brush rigging assembly for the generator end; and a brush-rigging assembly for the generator end; a fan; and two end covers, the motor end cover and the generator end cover.

Stator Assembly. The motor end of the stator assembly consists of a steel shell, eight pole pieces, eight series-connected shunt windings, and eight series-connected series windings. The generator end consists of the steel shell supporting two pole pieces and three separate series-connected windings: the series-quadrature field, the compensating field, and the control field.

End Covers. The ends of the stator are protected against damage by two sheet-aluminum covers: the motor-end cover, with ventilating slots in the sides, and the generator-end cover, with round ventilating holes in the end.

Rotor Assembly. The rotor assembly consisting of three balancing disks, a motor-armature core with a winding and a large-diameter commutator, a generator-armature core with a winding and a small-diameter commutator, and a shaft, is supported by the motor-and-generator-end bearings. The bearings are supported by the motor-end end shield and the generator-end end shield. Four clamp studs fasten the two end shields to the stator assembly. To complete the rotor assembly, the shaft is threaded and machined on the motor end to provide for the mounting of a nut, lock washer, fan, key, shim washers, and spring washer.

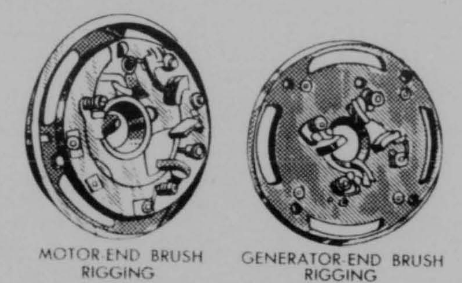

Figure 6—119. Brush-Rigging Assemblies Mounted on End Shields.

Brush-rigging Assemblies. (Figure 6-119.) The motor-end brush rigging is supported by the end shield and consists of a circular brush yoke which can be shifted for the proper brush position, six spring-supported brush holders, and six brushes. The rigging is connected to the stator assembly by a gray wire. The generator-end brush rigging, supported by the generator-end end shield, consists of a circular brush yoke, four spring-supported brush holders, and four brushes. This rigging is connected to the connector by a red wire and to the stator assembly by a yellow wire and two gray wires.

Fan. A fan is mounted at the motor end of

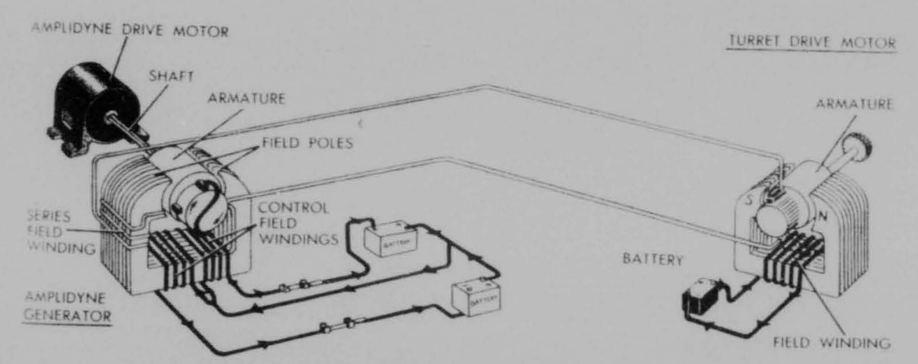

Figure 6—120. Amplidyne Turret Drive Motor Connections—Schematic View.

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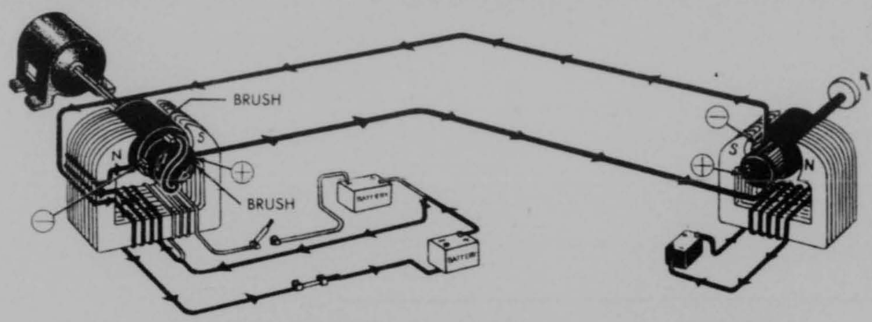

Figure 6–121. Amplidyne Turret Drive Motor Connections—Schematic View.

the rotor assembly shaft, between the end cover and the motor-end end shield.

Connector, Capacitor and Resistor. An AN connector to provide a means for quickly connecting and disconnecting the amplidyne, a capacitor to reduce radio interference, and a resistor to add additional resistance to the compensating winding complete the assembly. The capacitor is located under the cover plate opposite the connector assembly. The resistor is located under the cover plate just above the connector assembly.

Operation

The function of the amplidyne is to supply power for the turret-drive motor. The power to the drive motor must be direct current, capable of a wide variation in voltage. It also is necessary to reverse the direction of current flow. Polarity of the direct current must be reversed in order to drive the turret motor in the direction desired. In describing the operation of the amplidyne, the electrical principles by which it works will not be explained, but rather how it is controlled by the Selsyn-amplifier circuits, and how it, in turn, controls the turret-drive motor.

In Figure 6-120 there is a schematic representation of the amplidyne turret drive motor circuit. The turret-drive motor is shown at the right. In looking at the amplidyne generator it can be seen that it is similar in schematic construction to the turret drive motor. The amplidyne generator has an armature with its commutator, brushes, field poles, and control-field windings. It will be noted that the control-field winding is divided into two halves. In addition there is a compensating-field winding, and two brushes. These brushes, which are connected, are known as "short-circuited brushes."

The compensating-field winding and the short-circuited brushes are characteristic of the amplidyne generator but these will not be considered in an explanation of this system. They are important only in giving the amplidyne generator its unusual electrical characteristics.

The armature shaft of the amplidyne generator is shown connected to the amplidyne drive motor. Actually this motor and the amplidyne generator are built into one assembly and mounted as a single unit.

The amplidyne drive motor is actually connected to the airplane's direct-current supply which makes it run at a constant speed, always in the same direction, driving the amplidyne generator armature continuously clockwise as shown by the arrows on the generator commutator.

With the armature leads of the separately excited turret-drive motor connected to the amplidyne generator brushes, it can be seen that the driving of the turret motor will depend upon the direct-current voltage generated by the amplidyne-generator armature.

This amplidyne generator is no more than a direct-current generator in which the direct-current voltage produced within the constantly rotating armature depends upon the direction and amount of the magnetic path

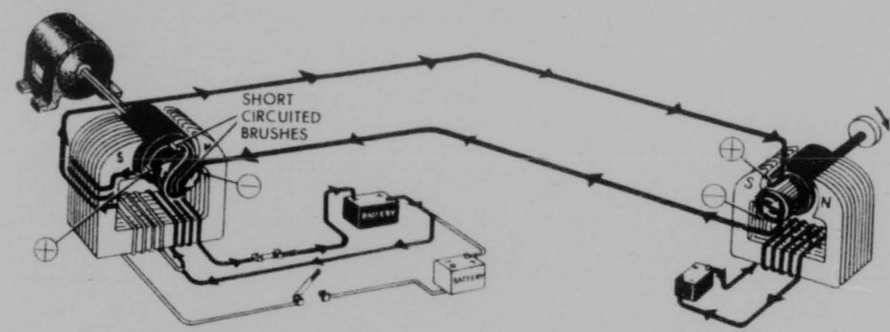

Figure 6–122. Amplidyne Turret Drive Motor Connections—Schematic View.

produced between the field poles by the control-field windings.

The amplidyne is made with two control-field windings. The control-field windings are wound on the field poles in such a way that if current (shown as arrows) through one winding is the same as current through the other winding, then the ends of the field poles are both magnetically north N which does not allow the rotating armature to generate a voltage since a magnetic path will not cross between like magnetic poles. Since there is no armature voltage generated, there is no power to the turret drive motor.

These two control-field windings may be compared to two teams playing "tug-of-war": when both teams pull the same, the rope stands still; if one team pulls harder than the other, the rope moves toward it. In Figure 6-121 there is more current, more pull through the left control-field winding and less or none through the right.

This makes the left field pole north N and the right field pole south S and thus gives a magnetic path between the unlike poles. A voltage is now generated in the amplidyne armature with the right brush positive and the left brush negative, causing the turret motor to turn counter-clockwise.

If the right winding gets more current than the left one, then the left brush becomes positive and the right brush negative, making the turret motor turn clockwise. See Figure 6-122.

Note: The central-station fire-control system using the amplidyne is concerned only with the balancing and unbalancing of the opposite control fields in the amplidyne.

The amplidyne generator is especially suited to the central-station fire-control system because this type of generator permits the use of a very small field current (represented by the arrows in Figure 6-122 to give a relatively large current represented by the arrows) from the generator armature. This proportion of armature current to field current is much higher than for ordinary generators, so from this it is evident that the amplidyne has a very high "amplification."

Amplidyne Symbol

The symbol for the amplidyne generator used in electrical diagrams is shown in Figure 6-123. Note the two control-field windings, the amplidyne armature, the compensating-field winding, the brushes (with the characteristic tie between two of them to indicate that they are short circuited) the shaft, and the drive motor. In the top view, the control-fields are shown balanced; in the two lower views, first one then the other control-field is shown with the greater amount of current.

Amplidyne Motor-generator connections

Power is brought to the amplidynes through an AN connector. This connector has seven pins, which are connected. See Figures 6-124 and 6-125.

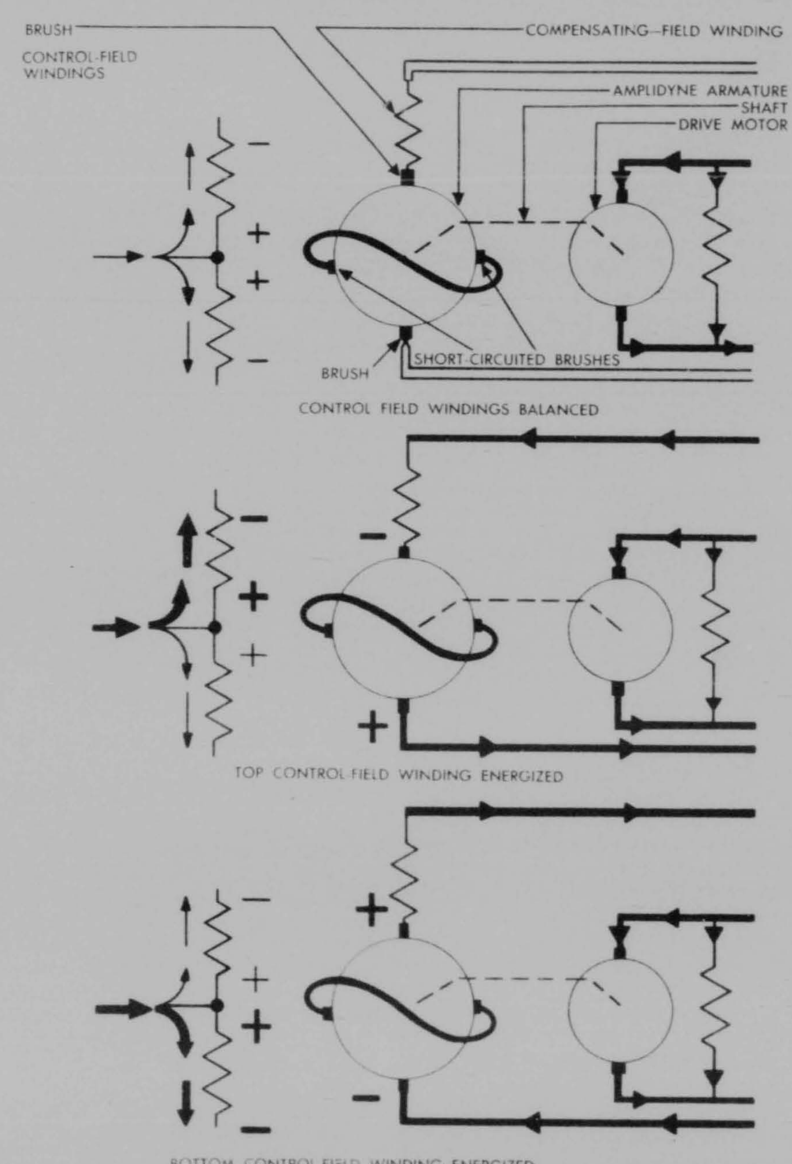

Figure 6—123. Electrical Symbol Representing Amplidyne Motor-Generator.

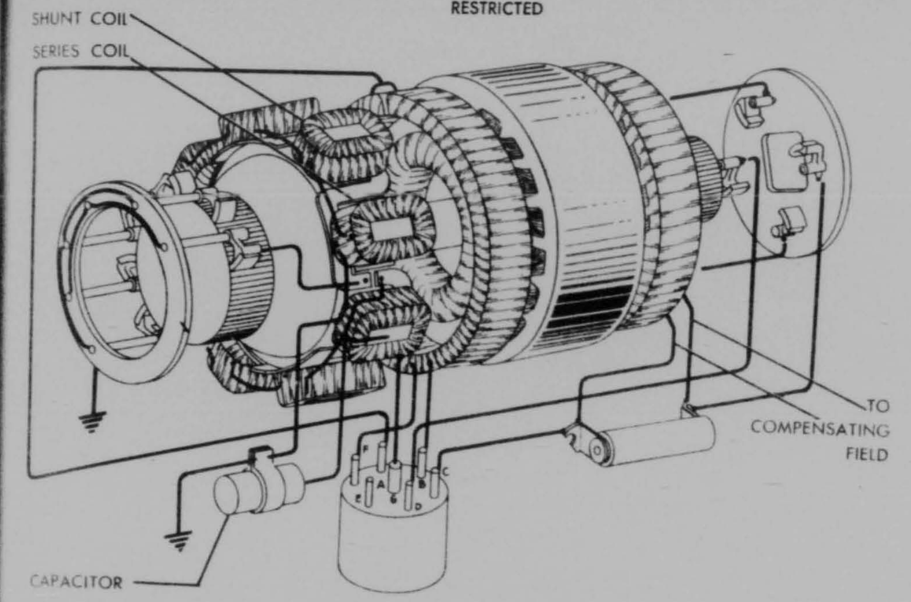

Figure 6—124. Amplidyne—Schematic View.

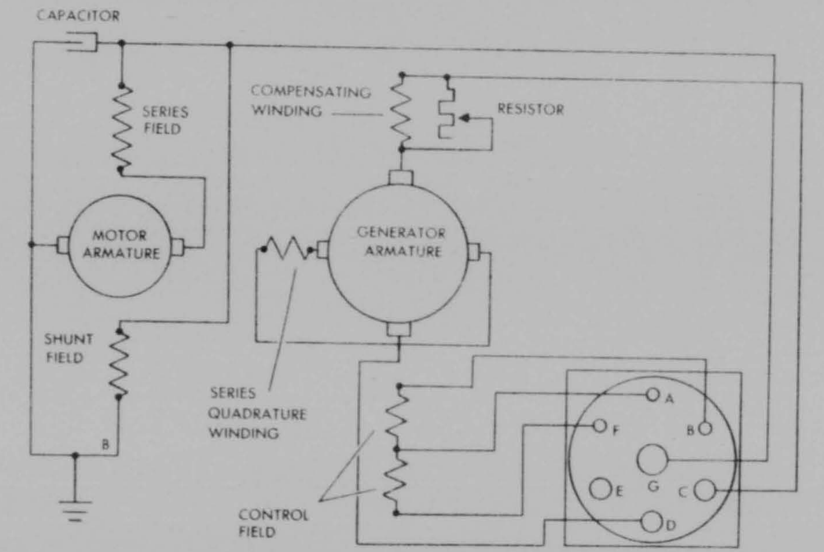

Figure 6—125. Connection Dingram for Amplidyne

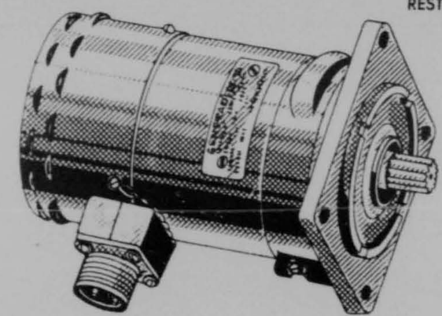

Figure 6—126. Assembled View Turret-Drive Motor.

2. DRIVE MOTORS

Lower-forward, Upper-aft, and Lower-aft Turrets

To parallel the line of fire with the line of sight, the turrets are moved in either azimuth or elevation by turret-drive motors. Since the outer rings of any of the four turrets is stationary with respect to the airplane, and the azimuth drive motor is mounted vertically on the inner-ring assembly, rotation of the motor causes rotation of the turret within the fuselage. The complete turret including dome, guns, ammunition frame, and ammunition, rotates in azimuth as a unit. And, since the pinion of the elevation-drive assembly mates with a gear sector on the gun saddle, rotation of the elevation drive motor causes the guns to elevate or depress depending on the direction or rotation. Thus, by a combination of azimuth and elevation turret-drive motors, the guns can be directed at any point in a hemisphere.

Rating

There is complete data on the direct-current motors (Figure 6-126) for the azimuth and elevation drive assemblies on the upper-forward turret, lower-forward turret, upper-aft turret, and the lower-aft turret. Reference should be made either to the motor nameplate or to following information.

INPUT	
Stator assembly (field)	
Volts, direct-current	28
Amperes, direct-current	2.3
Rotor assembly (armature)	
Volts, direct-current	60
Amperes, direct-current	8.3
OUTPUT	
Horsepower	0.5
Speed, rpm	4000

Structure. (See Figures 6-127, 128 and 129.)

Stator Assembly. The stator consists of a shell containing the field poles and field windings. The four pole pieces are bolted to a steel yoke which is pressed into the stator shell. The stator windings are assembled with the poles as their core.

Rotor. The rotor consists of a shaft on which are mounted the punchings with windings, the commutator, a balancing disk, and the ball bearings.

Commutator. The commutator consists of wedge-shaped bars of copper insulated from each other by strips of mica. These are assembled onto a steel support, and the entire unit is then pressed onto the shaft. Each end of

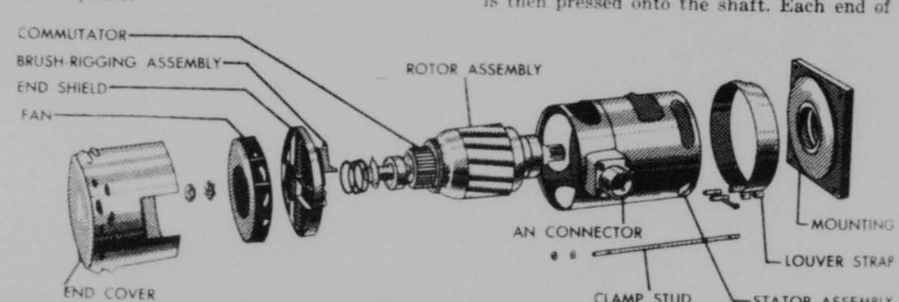

Figure 6—127. Turret-Drive Motor, Major Assemblies.

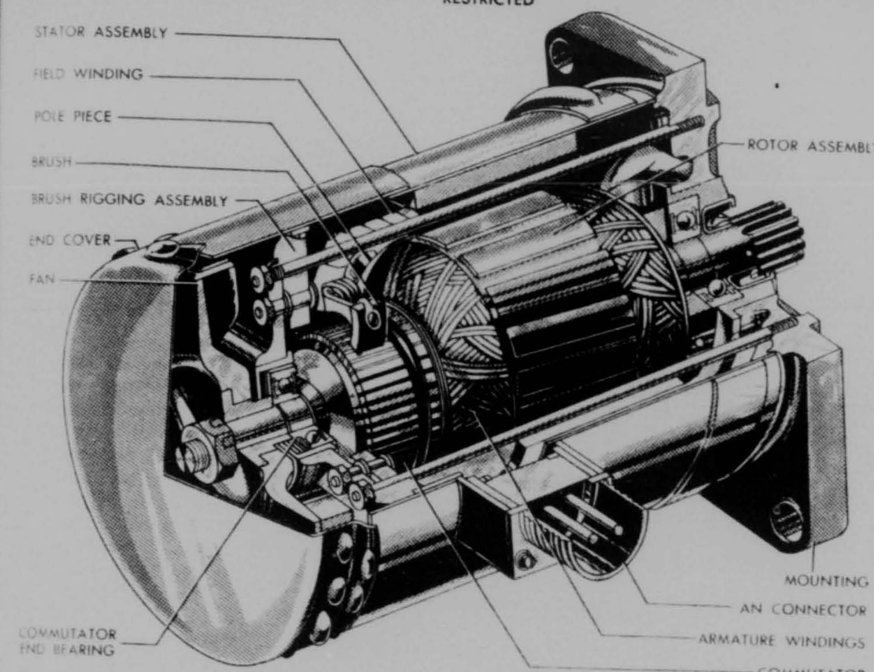

Figure 6—128. Three Quarter View Turret-Drive Motor.

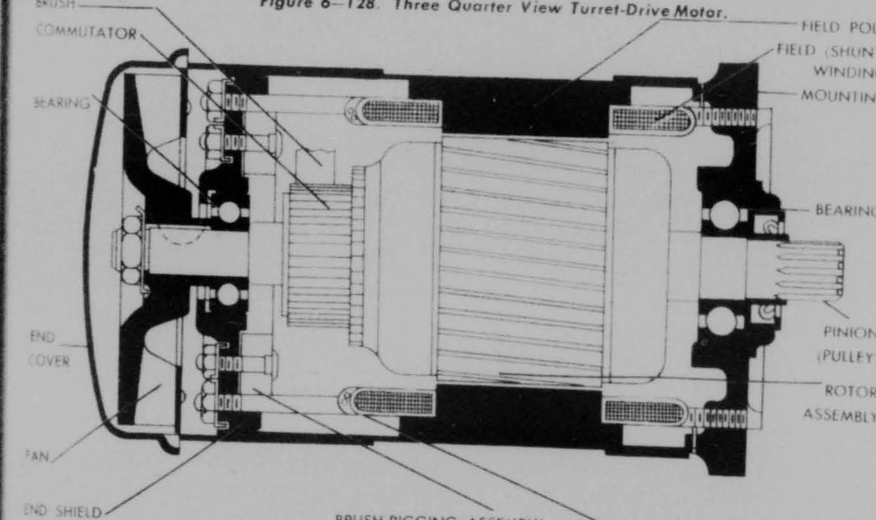

Figure 6—129. Cross Section View Turret-Drive Motor.

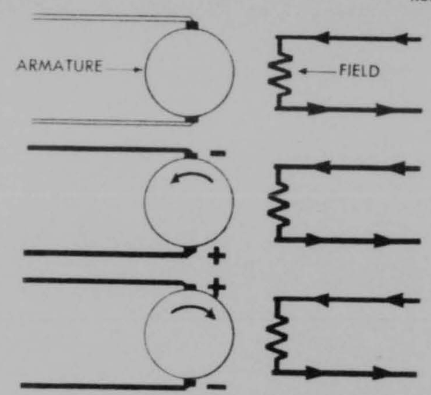

Figure 6—130. Turret Drive Motor Symbol.

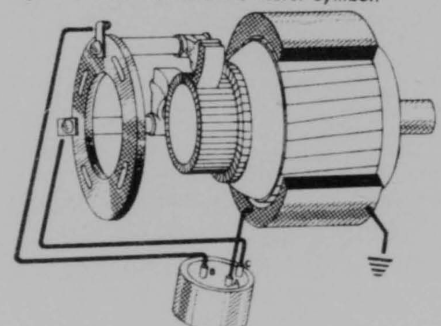

Figure 6—131. Schematic View. Connections for Turret Drive Motor.

each armature-winding coil is soldered to one of the commutator bars.

Bearings. The bearings are mounted one on either end of the rotor shaft, and fit into bearing housings in the end shields. The bearings are of the shielded, ball-bearing type.

End Shields. The end shields are fastened to the stator assembly by means of long clamp-stud bolts extending the length of the stator shell.

End-play Control. The rotor end play is controlled by means of shim washers and a spring washer located in the bearing housing of the commutator-end end shield. The spring washer allows the rotor shaft to expand and contract without danger of binding when hot, developing excess endwise motion when cold.

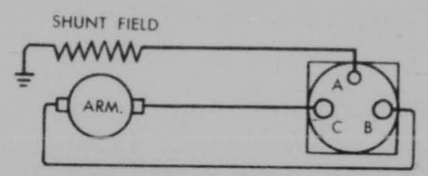

Figure 6—132. Diagram of Electrical Connection for Turret Drive Motor.

The end play may be adjusted by inserting or removing shim washers.

Brush Rigging. The brush rigging, together with the commutator, provides the means by which electrical connection is made between the stationary stator and the movable rotor. The brush rigging consists of an insulating yoke to which the brush holders are attached. The brushes are fastened in these brush holders by means of screws. They are kept in contact with the commutator bars by means of torsion springs which maintain a pressure against the brush holders. The brush yoke is mounted on the inner side of the commutator-end end shield by means of screws. Connection to the brush rigging is made by means of terminals mounted on the brush yoke.

External Connections. The connections from the power source to the stator windings and brush rigging are made by means of a receptacle mounted on the stator shell.

Operation

The model 5BA50LJ2A motor is a separately excited shunt-wound motor. This means that the field windings and armature windings are connected in parallel with each other and that current for the two windings is supplied from different sources.

Direction of Rotation. A reversal of rotor rotation in a direct-current motor may be accomplished by changing the relative direction of current flow through the field or armature windings. This is accomplished by changing the polarity of the connections to the armature windings.

Speed of Rotation. Separately-excited shunt-wound motors are useful in applications where variable speed control is desired.

The driving of a gun turret is such an application. The shunt-field voltage is supplied by a constant voltage from the plane generator and the armature voltage is supplied by the controlled variable-voltage source, the amplidyne motor-generator. Since the output of the amplidyne motor-generator may be varied both in polarity and in voltage, the direction of rotation and speed is controlled over a range of from zero to several thousand rpm.

Turret Motor Symbol

The schematic representation of the turret drive motor (Figures 6-131 and 6-132) will show how it can be controlled by the Selsyn-amplifier-amplidyne circuits. In actual practice on electrical diagrams, such schematic representation would take unnecessary space, so an electrical symbol for the motor is used. The turret-motor symbol is shown in Figure 6-130. In the top view, the field represented is energized by the aircraft generator at a constant voltage (27 volts). There is no voltage to the armature; therefore the motor does not turn. The two lower views (Figure 6-130) simply show the armature energized, with the top brush negative, and then with the top brush positive, and an indication of a reversed direction of rotation as the polarity is changed.

Turret Motor Connections

Power is brought to the turret drive motor through an AN connector. This connector has three pins marked respectively "A," "B," and "C."

Pin A is connected to the main DC supply of the airplane, and to the positive side of the motor field winding Figures 6-131 and 6-132). The negative side of the field is connected to ground.

Pins B and C are connected to the amplidyne output and to the brushes of the turret drive motor (Figure 6-131).

SECTION V—FOUR GUN TURRET, TAIL MOUNT, AND CONTROL BOXES

1. FOUR-GUN UPPER-FORWARD TURRET

General

The upper-forward turret is located in the forward crew nacelle.

Armament

Four cal. .50 machine guns. Each gun is furnished with approximately 925 rounds of ammunition carried in four ammunition cases designed to fit the contour of the frame assembly.

Approximate Dimensions

The over-all diameter across the dome is 48 inches. The over-all diameter across the ammunition cases is $41\frac{11}{64}$ inches. The overall height of the turret is $67\frac{11}{64}$ inches.

Approximate Weight in Pounds

The approximate weight of the turret fully loaded is 1,938 pounds.

Limits of Turret Movement

This turret rotates continuously through 360 degrees in azimuth and between —5 and +90 degrees in elevation. Power and control signals are introduced into the turret by a collector assembly which prevents the incoming cable from becoming twisted as the turret rotates. Guns are moved into alignment with the sight by an azimuth drive which rotates the guns in a horizontal plane, and by an elevation drive which moves the guns in a vertical plane.

Basic Parts of Upper-forward Turrets

(Figure 6-133.) The upper-forward turret

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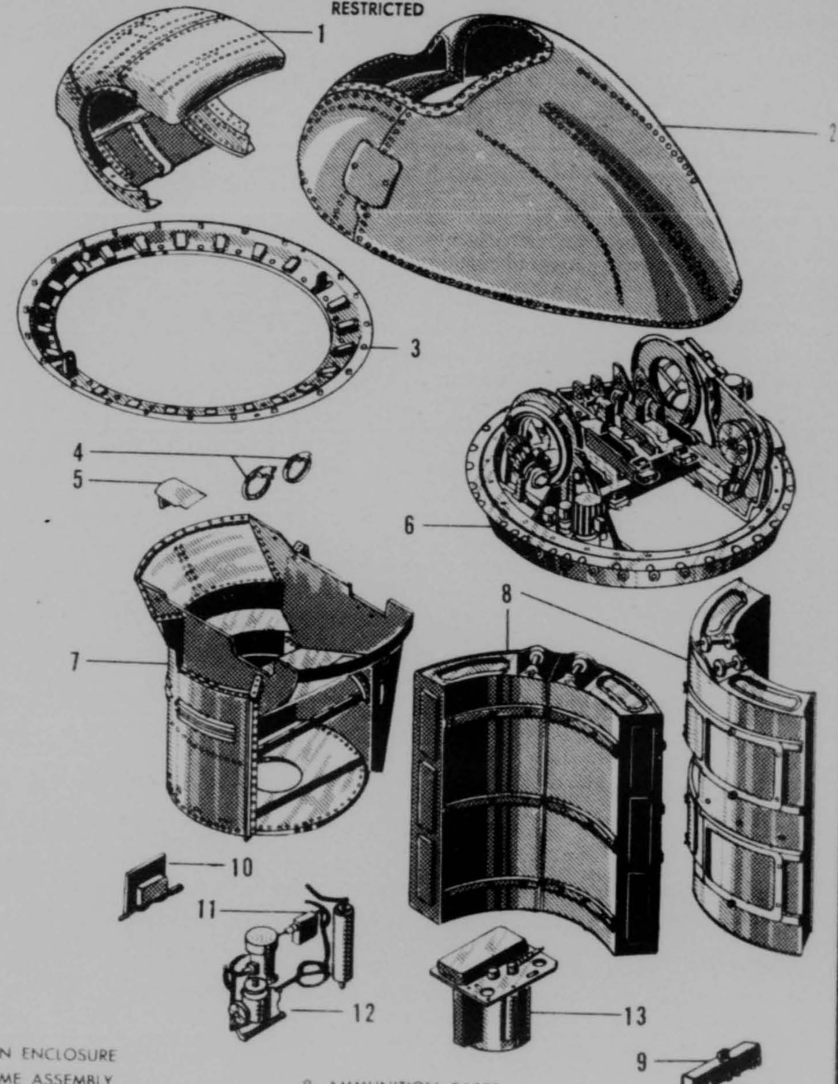
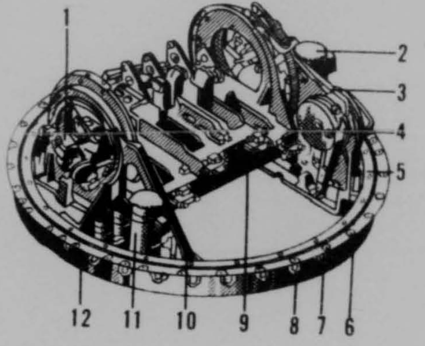


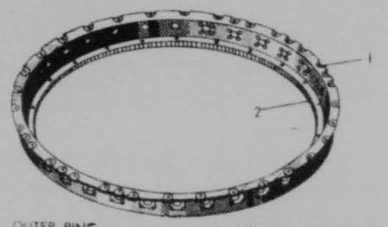
1. GUN ENCLOSURE
2. DOME ASSEMBLY
3. ADAPTER ASSEMBLY
4. ROUNDS-COUNTER ACTUATORS
5. AMMUNITION GUIDE
6. RING SUPPORTS AND DRIVE
7. AMMUNITION FRAME ASSEMBLY
8. AMMUNITION CASES
9. PULL BOX
10. JUNCTION BOX
11. RELAY
12. COMPRESSOR ASSEMBLY
13. INTERRUPTER AND COLLECTOR ASSEMBLY

Figure 6—133. Exploded View of Components of Four Gun Turret.



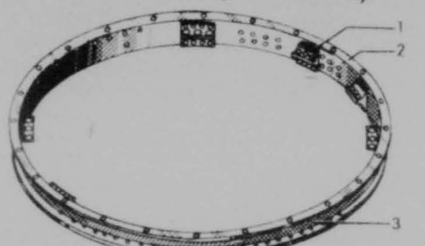
1. Booster assembly
2. Elevation drive
3. Saddle support
4. Contour follower
5. Inner ring
6. Outer ring
7. Radial bearing
8. Thrust bearing
9. Saddle assembly
10. Saddle support
11. Azimuth drive
12. Ring assembly

Figure 6—134. Ring Assembly Drives and Saddle Assembly.



1. OUTER RING 2. AZIMUTH RING GEAR

Figure 6—135. Outer Ring Gear Assembly.



1. T-SHAPED SUPPORTS 2. INNER RING
3. BEARING CHANNEL

Figure 6—136. Inner Ring Assembly.

consists of the following basic sub-assemblies:

Ring
Saddle supports
Saddle
Azimuth drive
Elevation drive
Stop
Contour follower
Booster
Machine guns and accessories
Dome
Ammunition frame and chute
Compressor and pressure cylinder
Ammunition cases
Interrupter drive
Interrupter and collector
Distribution cables and boxes

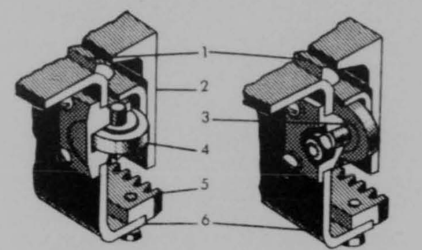
Rings, Supports, and Drives

(Figure 6-133.) The main assemblies of the rings, supports, and drives are the ring assembly on which the entire turret is mounted, the saddle-support assembly which supports the saddle assembly, and the drive assemblies which electrically drive the turret into alignment with the sighting station.

Ring Assembly. (Figure 6-134.) The purpose of the ring assembly is to secure the turret to the fuselage of the airplane and to furnish a mount on which the turret can continuously rotate through 360 degrees in azimuth.

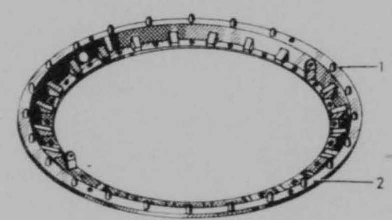
Components. The main components of the ring assembly (Figure 6-134) (12) are: an outer ring (6), inner ring (5), radial and thrust bearings (7 and 8) together with adapter and baffle assemblies which are attached to the ring assembly, but are not considered components.

Outer Ring and Azimuth Gear. (Figure 6-135.) The outer-ring assembly is a Z-shaped aluminum-alloy drawn ring, the upper flange of which is bolted to the airplane's fuselage so that the outer ring (1) remains stationary. The azimuth ring gear (2) is bolted to the lower flange and meshes with the main gear of the azimuth drive, which drives the turret in azimuth. A 32-bearing assembly bolted to the periphery of the outer ring ride in a track riveted to the inner ring. Protecting the inner turret from dirt, rain, and other foreign mat-



1. FELT SEAL
2. INNER RING
3. THRUST BEARINGS
4. RADIAL BEARINGS
5. RING GEAR
6. OUTER RING

Figure 6—137. Cutaway of Radial and Thrust Bearings.



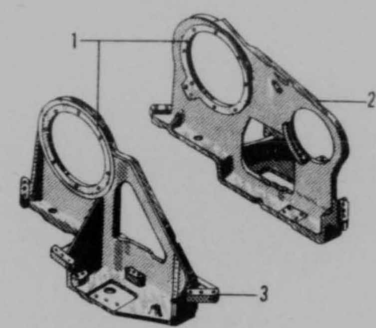
1. ANCHOR PIN 2. UPPER FLANGE OF ADAPTER

Figure 6—138. Adapter Assembly.

ter, is a felt seal, cemented on the upper-flange of the outer ring, filling the space between the inner and outer ring.

Inner-ring Assembly. (Figure 6-136.) This assembly is made of aluminum-alloy and is concentric with the outer ring. A stainless steel channel (3), riveted to its outer circumference guides the radial and thrust bearings that are bolted to the periphery of the outer ring. Five T-shaped aluminum pieces (1), riveted to the inner circumference (2) of the assembly, secure the saddle support assemblies which are bolted to its flange.

Radial Bearing Assembly. (Figure 6-137.) Sixteen radial bearings (4) are bolted between the sixteen thrust bearings (3) around the periphery of the outer ring (6). The radial bearings restrict the horizontal movement of the turret with respect to the outer ring. The tolerance between the track and the bearings must be sufficient to permit free operation of



1. TRUNNION BEARINGS
2. RIGHT-HAND SADDLE SUPPORT
3. LEFT-HAND SADDLE SUPPORT

Figure 6—139. Saddle Supports.

the turret and yet must prevent mechanical play.

Thrust-bearing Assembly. (Figure 6-137.) Sixteen thrust bearings (3) bolted around the periphery of the outer ring (6), absorb all vertical loads upward or downward including normal gravity loads plus additional loads due to diving and climbing, with guns in various positions. Sudden vertical loads caused by turbulent wind conditions, are also absorbed by the thrust bearings.

Adapter and Baffle Assemblies. (Figure 6-138.) The adapter is an aluminum-alloy assembly secured by its lower flange to the top of the inner-ring assembly. Twenty-three equally-spaced anchor pins (1), adapter facilitates installing the dome without catching on other components of the turret. Two steel baffles, attached to the bottom of the inner-ring assembly, cover the azimuth ring gear and prevent the ammunition from catching on the ring gear. They also prevent damage to the ring gear from the cal. .50 shell cases as they are fed to the gun. The adapter and baffle assemblies, attached to the ring assembly are not considered part of the ring assembly.

Saddle Supports (Figure 6-139.)

The saddle-support assemblies are aluminum-alloy castings mounted on the flange of the inner-ring assembly. The trunnion bear-

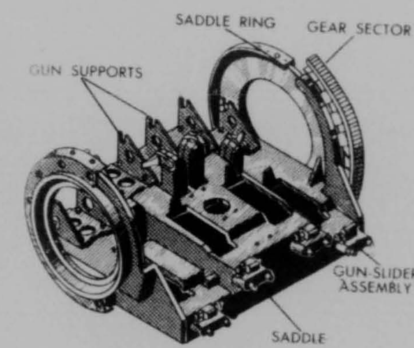


Figure 6—140. Saddle Assembly.

ings (1) support the saddle assembly within steel inserts and allow free movement of the guns in a vertical plane. The left-hand saddle support (3) mounts the azimuth drive assembly. The right-hand saddle support (2) mounts the elevation drive assembly, and the contour-follower mechanism. An ammunition booster assembly is attached to the outside of each saddle support.

Saddle Assembly (Figure 6-140.)

Function. The saddle assembly is supported between the left and right-hand supports, and mounts the four cal. .50 machine guns. Guns are elevated or depressed by the elevation drive, which engages the gear sector attached to the right-hand side of the saddle assembly. To allow ammunition to enter without restriction, the two center guns are mounted 2½ inches higher than the two outer guns.

Components

Gear Sector. (Figure 6-140.) The guns are elevated or depressed when the elevation drive pinion rotates and moves the gear sector. The gear sector is bolted and doweled to the saddle.

Supports. (Figure 6-141.) A recoil adapter fits over the barrel of each gun and mounts it to the saddle. The adapter is bolted to the gun support and absorbs most of the shock.

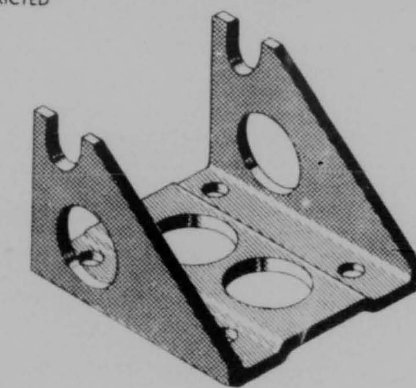


Figure 6—141. Gun Support.

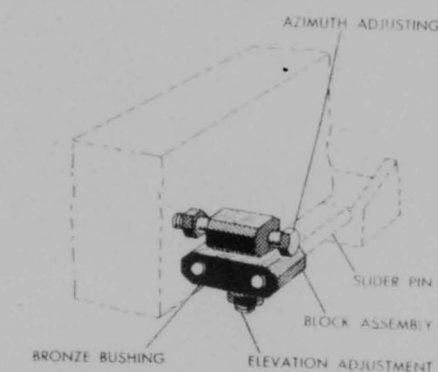


Figure 6—142. Gun Slider Assembly.

Gun-slider Assembly. (Figure 6-142.) The rear of each gun is mounted to the saddle assembly by a gun-slider assembly. This assembly consists of a block assembly with two bronze bushings, and elevation and azimuth adjustments. Two steel sliderpins are pressed in the rear of the saddle casting. The block assembly and bronze bushings which are attached to the gun, fit over the slider pins and ride fore and aft with the recoil action of the guns. Azimuth and elevation adjustments which permit alignment of the guns, are made by turning the adjusting screws on the block assembly. These adjustments are necessary when boresighting the guns.

Rotating Stop. This is a rectangular-shaped

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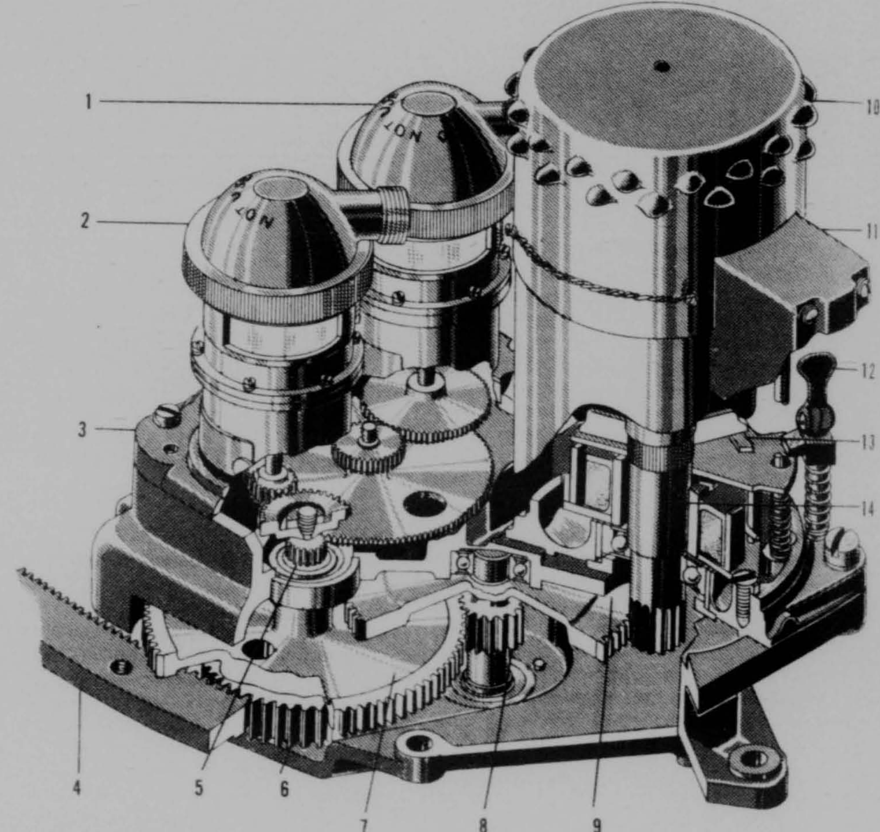

1. 1-speed selsyn
2. 31-speed selsyn
3. Selsyn mounting plate
4. Azimuth ring gear
5. Selsyn drive gear
6. Main drive gear
7. Intermediate gear
8. Pinion gear
9. Motor mating gear
10. Drive motor
11. Connector
12. Brake lever
13. Brake assembly
14. Drive shaft

Figure 6—143. Cutaway of Azimuth Drive Showing Gear Train.

RESTRICTED

piece of metal secured to the right side of the saddle just inside the gear sector. It engages a stop assembly on the saddle support, restricting the vertical travel of the guns at zenith.

Saddle-ring Assembly

(Figure 6-140.) The saddle rings are aluminum fittings mounted on the front of the saddle trunnions. They are designed to retain the upper and lower parts of the gun enclosure. The enclosures are attached to the saddle-ring assembly by means of fasteners.

Azimuth Drive Assembly
(Figure 6-143.)

Function. This assembly, located on the left-hand saddle support, positions the guns in azimuth. An electric motor (1) drives a set of speed-reduction gears that mesh with the azimuth ring gear (4). The Selsyn control-transformer rotors are connected through a second gear train to the drive motor and transmit a gun-position signal.

Components

Drive Motor. The azimuth drive motor is rated at ½ horsepower, and is a "separately-excited" motor that rotates either clockwise or counterclockwise according to the signal from the amplidyne generator. Input voltage from the amplidyne generator controls the motor's speed. A solenoid-operated brake, located at the base of the motor, prevents rotation of the drive motor armature when the motor is not energized. When the motor armature is locked by the brake, the turret cannot rotate in azimuth. The brake can be released manually by two spring-loaded levers, one located on each side of the motor.

Gear Assembly. (Figure 6-143.) The purpose of the power-gear assembly is to transmit power from the drive motor (10) through a set of speed-reduction gears to the main drive gear (6) and to the Selsyn drive (5). The main drive gear meshes with the azimuth ring gear (4) and turns the turret in azimuth. The Selsyn-gear system is located above the power gear assembly and is driven by a driving gear attached to the main shaft of the power gearing.

Power Gearing. (Figure 6-143.) The power-gearing assembly consists of a gear case, cover Selsyn mounting plate (3) and a gear train with four gears which is designed to reduce the motor speed. The power gearing is located in the lower part of the gear case. Power is transmitted from the drive-motor armature-shaft to the motor mating-gear (9) which is attached to the pinion (8), and is supported vertically in two bearings. The pinion transmits power to the intermediate gear (7) which is bolted and doweled to the main shaft and meshes with the azimuth ring gear (4), completing the power gear train.

Selsyn Rotor Position Gearing. (Figure 6-143). The Selsyn gearing is located in the top section of the gear case. The Selsyn drive gear (5) is keyed to the main shaft and is machined with two rows of gear teeth. The top row of teeth meshes with the 31-speed Selsyn gear which is keyed to the Selsyn rotor. The gear ratio is increased at this point to increase the speed of the Selsyn rotor to 31 revolutions for every revolution of the turret. The lower row of teeth on the Selsyn drive gear (5) meshes with the Selsyn idler gear which is secured to the hub gear. The 1-speed Selsyn gear engages the hub gear and turns the Selsyn rotor once for every revolution of the turret in azimuth. The Selsyn control-transformers indicate by means of an electrical control signal, the azimuth location of the guns in relation to the azimuth location of the line-of-sight.

Elevation Drive Assembly
(Figure 6-144.)

(1) **Function.** This assembly, located on the right-hand saddle support, positions the guns in elevation by means of an electric motor (1) and a set of speed-reduction gears which mesh with the elevation gear sector. Two Selsyn control-transformers are mounted horizontally on the elevation drive assembly. Their operation is identical to that of the Selsyn control-transformers on the azimuth drive.

Components

Drive Motor. (Figure 6-144.) The elevation- and azimuth-drive motors are identical.

Gear Assembly. (Figure 6-144.) The gear assembly consists of a gear case (2) and cover

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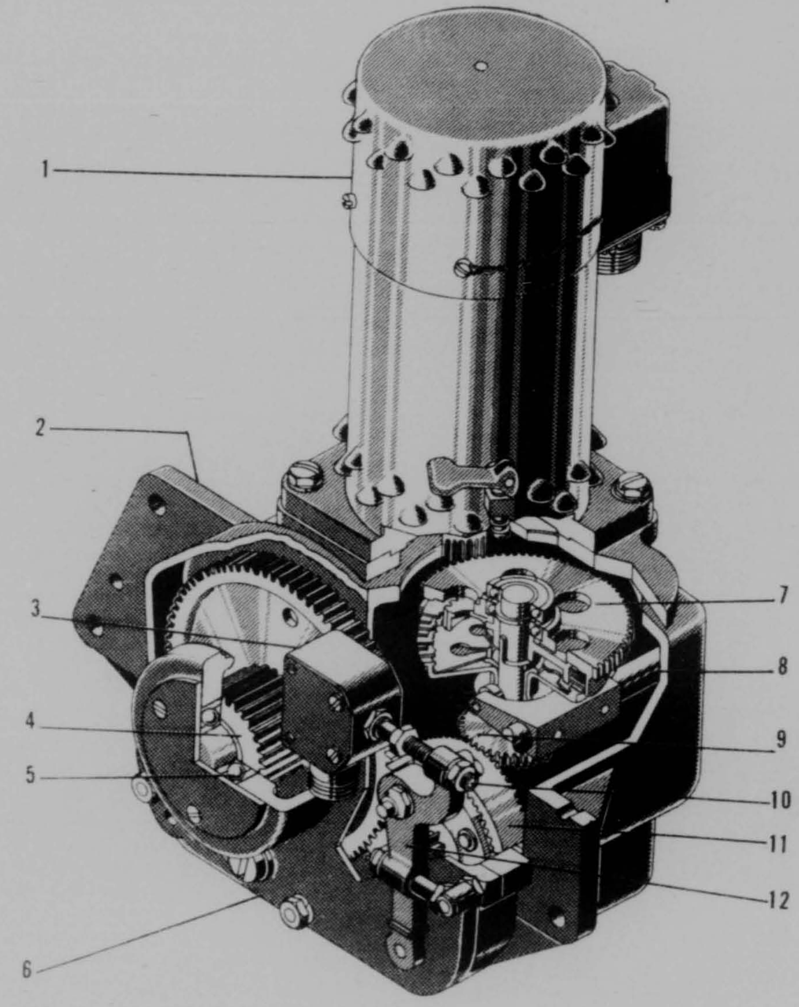
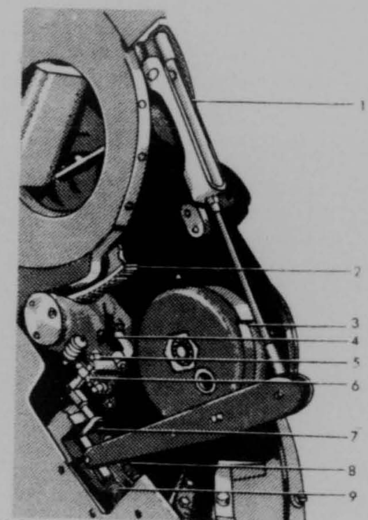


1. Motor
2. Gear case
3. Switch
4. Main pinion gear
5. Bearing
6. Cover
7. Clutch assembly
8. Clutch lever assembly
9. Clutch pinion bevel gear
10. Pin (switch actuator)
11. Intermediate gear assembly
12. Crank

Figure 6–144. Cutaway View of Elevation Drive Assembly.



1. YOKE AND ROD ASSEMBLY
2. GEAR SECTOR
3. CAM
4. ELEVATION DOWN-STOP SWITCH
5. CLUTCH LINKAGE
6. CLUTCH-ROD STOP
7. BRACKET ASSEMBLY
8. CLUTCH-MECHANISM SPRING
9. LEVER ASSEMBLY

Figure 6–145. Contour Follower.

(6), a Selsyn mounting plate, clutch assembly (7), and a speed-reduction-gear train. The elevation power-gear assembly transmits power from the elevation drive motor (1) to the elevation gear sector through the speed-reduction gears and clutch assembly (7). The two elevation Selsyn control-transformers are driven by two Selsyn drive gears on the main pinion-gear shaft.

Power Gearing. (Figure 6-144.) The elevation power gearing reduces the motor speed and increases its driving torque. Power is transmitted from the motor-armature-drive to the clutch gear and through a clutch assembly (7) to the pinion bevel gear (9). The pinion bevel gear drives the intermediate gear and the intermediate gear assemblies (11). The intermediate gear assembly (11) consists of a planetary system which meshes with the minor pinion gear, and a second pinion bevel gear driving interrupter drive shaft. The minor

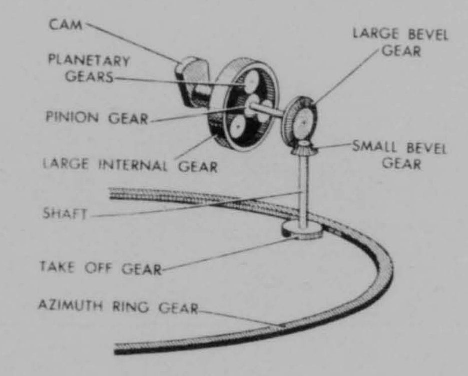


Figure 6–146. Schematic Drawing of Contour Follower Mechanism.

pinion meshes with the last reduction gear which is on the same shaft as the main pinion gear (5). The main pinion gear meshes with the elevation gear sector completing the power gear train.

Selsyn Rotor Position Gearing. (Figure 6-144). The Selsyn control-transformers are mounted on the Selsyn mounting plate by two clamps and screws. The Selsyn drive gears are keyed to the main and pinion shaft. The top gear meshes with the 31-speed Selsyn gear which is secured to the rotor shaft of the Selsyn control-transformer. The lower Selsyn drive gear meshes with the Selsyn idler gear and drives the hub gear which is attached to the idler gear by three screws. The hub gear meshes with the 1-speed Selsyn gear and transmits motion to the rotor shaft of the 1-speed Selsyn control transformer.

Selsyn,Control Transformers. The elevation Selsyn control transformers are identical in operation and construction to the azimuth Selsyn control transformers.

Stop Assembly

Function. The stop assembly restricts the upward motion of the guns at their maximum travel limit. The travel in elevation is limited to 90 degrees zenith by a fixed stop. The permissible downward travel of the guns varies with the turret azimuth position and is controlled by the contour-follower assembly.

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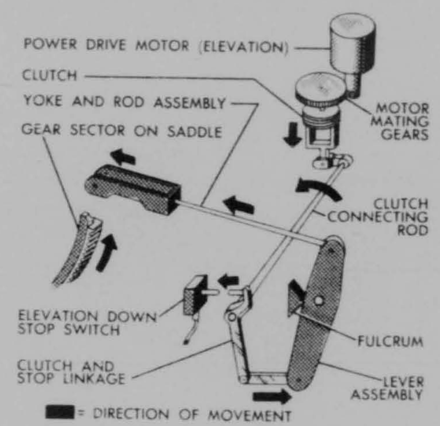


Figure 6–147. Schematic Drawing of Clutch Mechanism.

Components

Zenith Stop Assembly. The zenith stop assembly consists of an aluminum block with a rubber buffer which is attached to the (right-hand) saddle support. A similar block without the rubber buffer is attached to the saddle The fixed stop engages the stop on the saddle and restricts the upward motion of the guns.

Contour Follower
(Figures 6-145 and 6-146)

Function. The purpose of the contour follower is to limit the downward travel of the guns in all azimuth positions and to prevent the line of fire from pointing at the upper-gunner's sighting station. When the guns approach their maximum travel downward, the elevation gear sector (Figure 6-145) engages the yoke and rod assembly (1) which is attached to the upper part of the lever assembly (9). As the guns continue their downward travel, the rod assembly pulls the top part of the lever assembly forward. The lever rides on a cam (3) which changes position as the turret moves in azimuth. The bottom of the lever assembly is connected to the clutch-mechanism assembly (8) which restricts the downward travel of the guns. A clutch assembly and a limit switch (4) work simultaneously with the clutch mechanism to disengage the power drive from the gear train and to break the power and firing circuit in the down direction only.

Components

Yoke and Rod Assembly. (Figures 6-145 and 6-147). The yoke and rod assembly (1, Figure 6-147) consists of a steel rod attached to the top of the lever (9) assembly and a yoke that engages the elevation gear sector (2) as the guns approach their maximum downward limit.

Contour Follower Mechanism. (Figure 6-146). The contour follower mechanism consists of a speed-reduction gear train with a cam splined to the large internal gear. The cam acts as a movable fulcrum point for the lever assembly and changes position as the azimuth position of the turret changes. The contour-follower take-off gear engages the azimuth ring gear and transmits the motion of the turret in azimuth through two bevel gears to a pinion gear. The pinion engages three planetary gears which drive the large internal gear.

Lever Assembly. (Figure 6-145.) The clutch mechanism is fastened to the lower end of the lever assembly. It consists of a system of springs and shafts which has three functions:

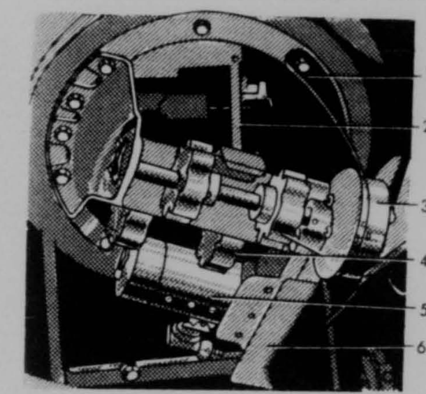
To limit the downward movement of the guns by means of a fixed stop.

To absorb within a total movement of ½ inch the downward inertia of the guns before hitting the fixed stop above.

To simultaneously operate the elevation-drive-clutch lever mechanism, which operates the elevation limit switch and disengages the elevation drive clutch. The limit switch simultaneously breaks the firing circuits, engages the elevation-drive-motor brake, and breaks the power circuit. As the elevation drive clutch is relaxed, disengaging the motor from the drive. Thus the large inertia of the motor is not transmitted through the gear train to the fixed stop.

Left and Right Booster Assemblies
(Figure 6-148)

Function. Boosters are used to assist in the feeding of the ammunition. The ammunition is lifted from the ammunition case by the booster motor-power sprockets (4) and shaft



1. BRACKET
2. GUIDE SPRING
3. POWER GEARING
4. SPROCKETS
5. MOTOR
6. AMMUNITION GUIDE

Figure 6–148. Booster Assembly.

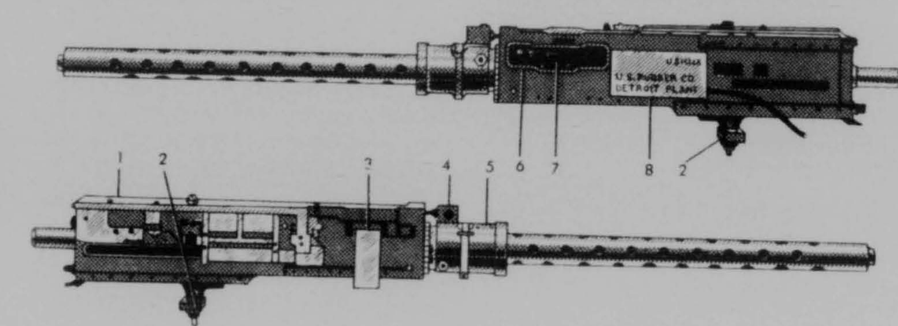
assembly and fed into the guns. Each gun is fed by a separate sprocket and shaft assembly. Each booster assembly has two sets of sprockets (4) and one motor (5).

Components

Bracket Assemblies. (Figure 6-148.) The bracket assemblies (1) are bolted to the saddle supports, and mount the gear assemblies (3), power motors (5), and the sprocket assemblies (4).

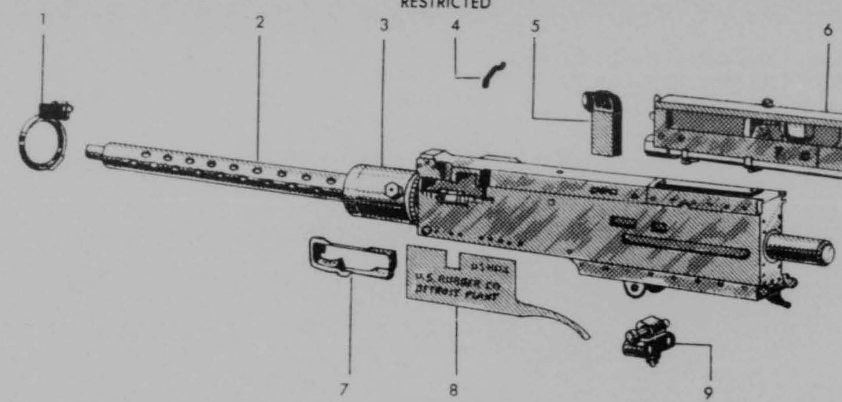
Gear Assembly. (Figure 6-148.) The gear assembly (3) is designed to reduce the speed of the drive motor (5) and to drive the sprocket assemblies (4). Power is transmitted from the drive motor armature shaft to the motor-mating gear and to the pinion gear which is attached to the same shaft. The pinion gear meshes with the drive gear which drives the lower sprocket shaft. An intermediate gear meshes with the upper sprocket shaft. Free-wheeling within the gear assembly allows the sprocket to turn, when ammunition is being fed into the gun, and acts as a brake when the sprocket tends to turn in the opposite direction.

Sprocket Assemblies. (Figure 6-148.) Two rubber sprockets (4) are attached to each



1. GUN CHARGER
2. GUN-SLIDE ASSEMBLY
3. LINK CHUTE
4. ROUNDS-COUNTER ACTUATOR
5. RECOIL ADAPTER
6. FEED GUIDE (BELL-MOUTH)
7. CARTRIDGE POSITIONER
8. GUN HEATER

Figure 6–149. Overall View Caliber .50 Machine Gun.



1. ROUNDS-COUNTER ACTUATOR
2. GUN
3. RECOIL ADAPTER
4. CARTRIDGE POSITIONER
5. LINK CHUTE
6. GUN CHARGER
7. FEED GUIDE (BELL-MOUTH)
8. GUN HEATER
9. GUN-SLIDER ASSEMBLY

Figure 6–150. Exploded View of Accessories of Caliber .50 Machine Gun.

drive shaft. They are designed to fit the contour of the cal. .50 ammunition. The sprocket assemblies are driven by an electric motor (5) through a speed-reduction gear train. The sprocket assemblies rotate, when the firing circuit closes, lifting ammunition from the ammunition cases and feeding it into the guns. The rubber sprockets are designed so that ammunition can slide over them to prevent jamming when ammunition is fed too fast. The upper and lower guides (6) keep the ammunition in place. The upper sprocket and shaft assembly on each booster assembly feeds the center gun, and the lower sprocket feeds the outside gun.

Cal. .50 Machine Gun and Accessories

(Figure 6-149)

Function. The four cal. .50 machine guns operate automatically from recoil action. The first cartridge is injected into the gun by an automatic gun charge (1) which actuates the cocking mechanism by compressed air. The gun charger (1) also ejects dud shells. A recoil adapter (5) is mounted on the gun in the front, and a gun-slider assembly (2) in the rear. A gun heater (8) is installed on each gun to prevent freezing of the gun. A rounds-counter actuator (4), which consists of a small snap-action switch which opens and closes a circuit to the rounds counter every time a shot is fired, is mounted on the two center guns. The gun accessories also include a link chute (3), feed guide (6), and a cartridge positioner (7).

Components

Gun Charger. (Figure 6-150.) The gun charger (6) cocks the gun (2), injects the first shell into the gun and fires the gun. It also clears the gun of defective ammunition in case of misfire.

Recoil Adapter. (Figure 6-150.) The recoil adapter screws on the barrel jacket of the gun and contains two mounting bolts. An intermediate gear meshes with the upper drive gear and drives the upper sprocket shaft. Free wheeling within the gear assembly allows the sprocket to turn, when ammunition is being fed into the gun, and acts as a brake when the sprocket tends to turn in the opposite direction.

Sprocket Assemblies. (Figure 6-148.) Two rubber sprockets (4) are attached to each drive shaft. They are designed to fit the contour of the cal. .50 ammunition. The sprocket assemblies are driven by an electric motor (5) through a speed-reduction gear train. The sprocket assemblies rotate, when the firing circuit closes, lifting ammunition from the

ammunition cases and feeding it into the guns. The rubber sprockets are designed so that ammunition can slide over them to prevent jamming when ammunition is fed too fast. The upper and lower guides (6) keep the ammunition in place. The upper sprocket and shaft assembly on each booster assembly feeds the center gun, and the lower sprocket feeds the outside gun.

Cal. 50 Machine Gun and Accessories

(Figure 6-149)

Function. The four cal. .50 machine guns operate automatically from recoil action. The first cartridge is injected into the gun by an automatic gun charger (1) which actuates the cocking mechanism by compressed air. The gun charger (1) also ejects dud shells. A recoil adapter (5) is mounted on the gun in the front, and a gun-slider assembly (2) in the rear. A gun heater (8) is installed on each gun to prevent freezing of the gun. A rounds-counter actuator (4) which consists of a small snap-action switch, opens and closes a circuit to the rounds counter every time a shot is fired is mounted on the two center guns. The gun accessories also include a link chute (3), feed guide (6), and a cartridge positioner (7).

Components

Gun Charger. (Figure 6-150.) The gun charger (6) cocks the gun (2), injects the first shell into the gun and fires the gun. It also clears the gun of defective ammunition in case of misfire.

Recoil Adapter. (Figure 6-150.) The recoil adapter screws on the barrel jacket of the gun and contains two mounting bolts for mounting the front of the gun to the saddle assembly. The recoil adapter is designed to absorb and lessen the shock caused by the recoil of the guns. The recoil adapter is Government-furnished equipment.

Link Chute. (Figure 6-150.) The link chute (5) is a metal fitting attached to the inboard side of the gun (2). It is attached to the pawl pin and directs the links downward into the turret well.

Gun Heater. (Figure 6-150.) Each gun is equipped with a gun heater (8) which consists of a resistance coil assembly, attached to the side of the gun. The gun heaters are used to furnish heat to the working parts of the gun.

Gun Slider. (Figure 6-150.) The guns are mounted, at the rear, by the gun sliders (9) which permits the horizontal motion of the guns caused by recoil.

Rounds-counter Actuator. (Figure 6-150.) The rounds-counter actuator (1) is located on the recoil adapter and consists of a recoil actuated snap action switch that opens and closes the ammunition recorder circuit each time the gun recoils. The rounds-counter records the shots fired and keeps the gunner informed as to the ammunition supply.

Gun-feed Guide. The feed guide (bell mouth) (7) is secured by a pawl pin to the outside of the gun. This guide prevents the ammunition belt from catching on sharp surfaces as the ammunition enters the gun (2).

Ammunition Guide. The ammunition guide is a steel plate that fits over the top of the two outside guns and guides the ammunition into the center guns. The ammunition guide prevents the cartridges from catching on rough surfaces of the outside guns.

Cartridge Positioner. (Figure 6-150.) The cartridge positioner (4) is a small metal device attached to the side of the two left-hand guns by the pawl pin. As the cartridge enters the gun (2) it is positioned by this device, which is shaped to fit the contour of the cartridge. The cartridge positioner is used on left guns only.

Gun Enclosure

(Figure 6-151). The gun enclosure is designed to follow the contour of the dome assembly and consists of three sections. The lower section is secured to the saddle ring and covers the guns when they are elevated. The second section fits over the guns and is secured to the saddle ring by quick-disconnect fasteners. The top section projects the top of the guns and is also fastened to the saddle ring.

Dome Assembly

(Figure 6-152). The dome assembly is a

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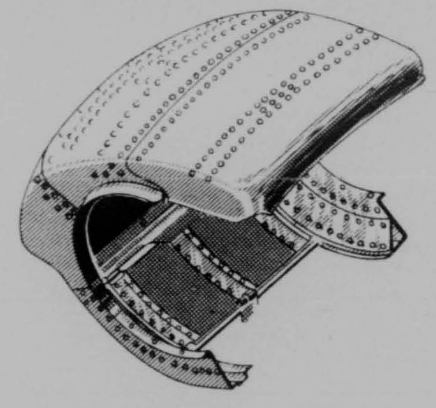
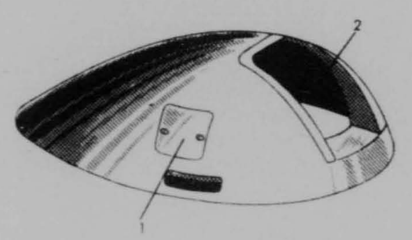
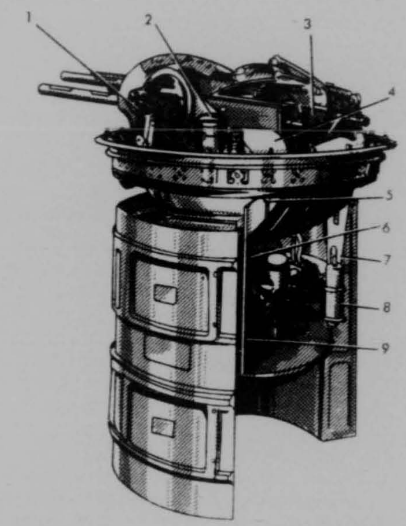


Figure 6—151. Gun Enclosure.



1. ACCESS DOORS
2. WIRE-LOCK ASSEMBLY

Figure 6—152. Dome Assembly.



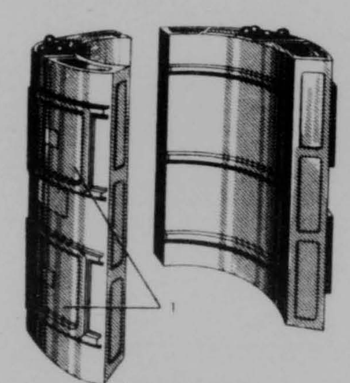
1. BOOSTER
2. AZIMUTH DRIVE
3. MACHINE GUNS AND ACCESSORIES
4. PULL BOX
5. INTERRUPTER DRIVER
6. INTERRUPTER AND COLLECTOR ASSEMBLY
7. AMMUNITION FRAME
8. PRESSURE CYLINDER
9. COMPRESSOR

Figure 6—153. Three-Quarter View of Four-Gun Turret, Dome Removed.

streamlined aluminum cover for the turret. The dome assembly is secured to the adapter assembly by 23 equally-spaced anchor pins located on the upper flange of the adapter assembly. The dome is locked on the adapter by a wire-lock assembly (2) which is actuated by the latch assembly, located on the right-hand side of the turret. The dome assembly is designed with an access door (1) on each side of the turret. Two spring-loaded J-shaped safety locks engage the brackets on the adapter and lock the dome assembly in place.

Ammunition Frame and Chute Assembly

(Figure 6-133). The ammunition frame (7) (Figure 6-133) is attached to the saddle supports, innerring assembly, and mounts the ammunition cases (8). The ammunition cases are designed so they are concentric with the ammunition frame, and are secured to the frame by quick-disconnect fasteners. The chute assembly is a metal-assembly that directs the empty shells downward into the turret well.



1. ACCESS DOORS

Figure 6—154. Ammunition Cases.

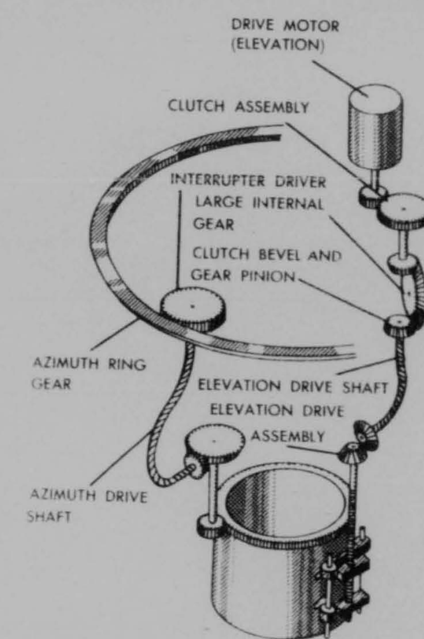


Figure 6—155. Schematic Drawing of Interrupter Drive Assembly.

Compressor and Pressure Cylinder

(Figure 6-153). The four-gun turret is equipped with a motor-driven compressor (9) and a pressure cylinder (8) which supplies the automatic gun chargers (3) with compressed air.

Ammunition Cases

(Figure 6-154). The four ammunition cases are fastened to the ammunition frame by quick-disconnect fasteners. Each case holds approximately nine-hundred rounds of ammunition plus approximately twenty-five rounds between cases and their respective guns. The early model cases are designed with two access doors, one at the bottom of the case and one at the top. Later models are designed with one door at the top. The access doors (1) allow handling of the ammunition when it is being lowered into the case.

Interrupter Driver Assemblies

(Figure 6-155.) The interrupter assembly is driven in azimuth corresponding to the azimuth rotation of the turret. The azimuth take-off gear transmits turret azimuth motion through a flexible cable, two bevel gears, and two spur gears rotating the cam drum of the interrupter assembly. The elevation interrupter drive transmits turret elevation motion through a flexible cable, two bevel gears, and to a worm pinion. The worm gear rotates as the saddle moves in elevation and drives the fire-interrupter up or down to correspond to the elevation position of the saddle.

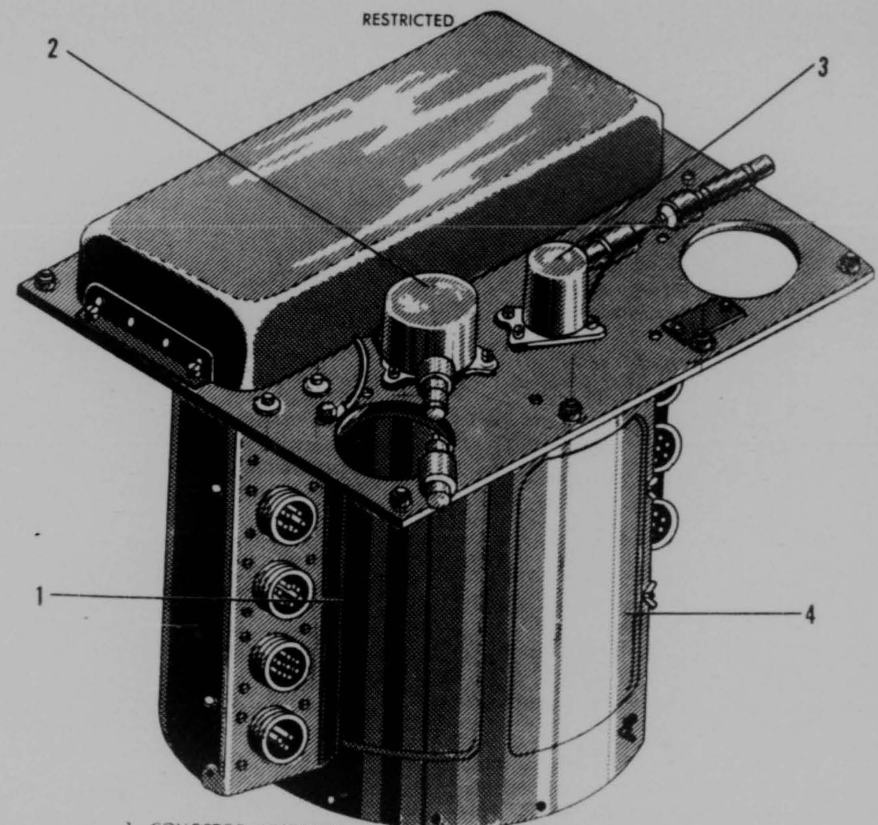
Interrupter and Collector Assembly
(Figure 6-156)

Function. The interrupter assembly prevents the guns from firing into aircraft (including propellers) by opening the firing circuit when guns are pointed at these surfaces. The collecter ring assembly provides a means of introducing power into the turret, permitting continuous rotation without twisting incoming cables.

Components

(Figures 6-157 and 6-158). The main components of the interrupter and collector assembly are the interrupter assembly, cam assembly (1) (Figure 6-157), switch-carriage (3), snap-action switches (7), collector assembly (Figure 6-158), and the brush-housing assembly (5).

Interrupter Assembly. (Figure 6-157.) The interrupter assembly consists of a cam assembly (1), a switch-carriage assembly (3), and two drives (4 and 5). When the interrupter assembly is rotated in azimuth the switch-carriage assembly rides over the cam assembly preventing the guns from firing at exposed parts of the aircraft structure.

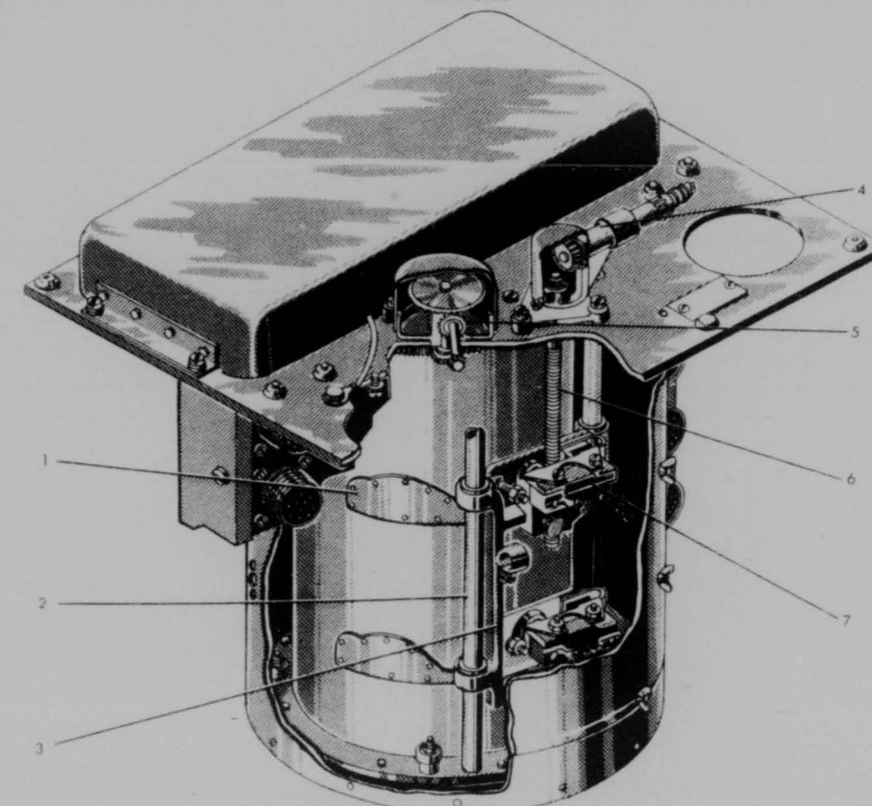


1 COLLECTOR ASSEMBLY
2 AZIMUTH DRIVE
3 ELEVATION DRIVE
4 ACCESS DOOR

Figure 6—156. Interrupter and Collector Assembly.

Cam Assembly. (Figure 6-157.) The cam assembly (1) consists of two sets of corrosion-resistant steel cam patterns. Each cam pattern represents an area such as the propeller area, for which fire must be interrupted. As the guns are turned in azimuth, the cam drum remains stationary with reference to the airplane. This is done to keep the cams in a fixed position with reference to airplane surfaces which they protect from gun fire. It is accomplished by driving the cam drum at the same speed, and in a direction opposite to the rotation of the turret. The cam drum is driven by a drive assembly connected to the azimuth ring gear.

Switch Carriage Assembly. (Figure 6-157.) The switch carriage mounts two small snap-action switches (7) that are normally closed, and are used to interrupt the fire of the guns. The switch-carriage assembly (3) is mounted on two cylindrical rods. These guide rods (2) are supported by the top and bottom plate assembly. The switch carriage is moved up and down on the guide rods by a screw shaft actuated by the elevation drive (4). When the guns are elevated or depressed, the switch carriage moves correspondingly. When the turret revolves in azimuth, the switch carriage moves correspondingly duplicating the movement of the guns.

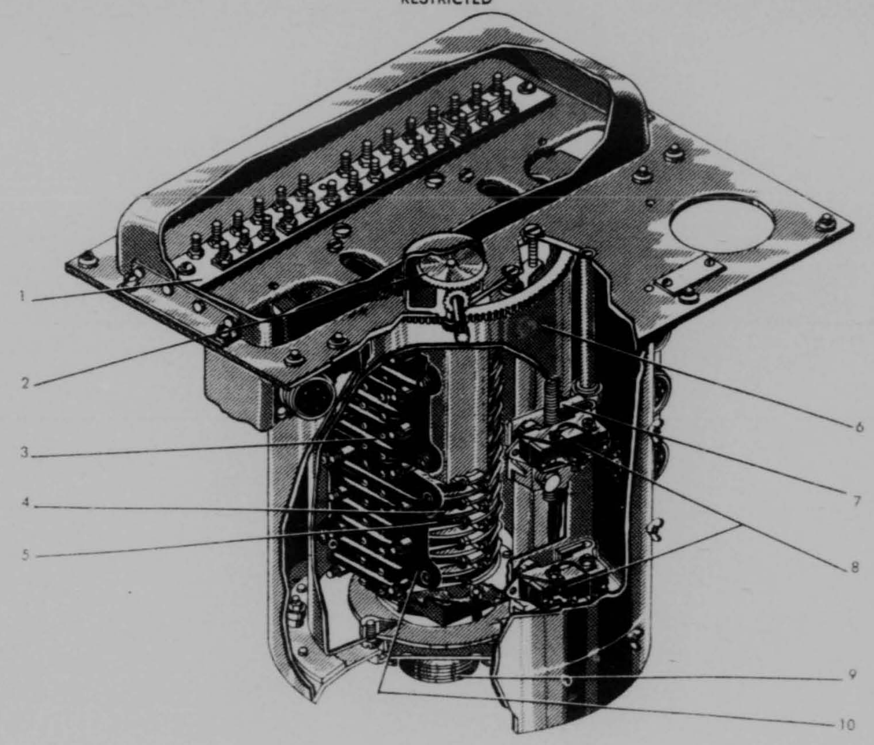


1 CAM ASSEMBLY
2 GUIDE ROD
3 SWITCH-CARRIAGE ASSEMBLY
4 ELEVATION DRIVE
5 AZIMUTH DRIVE
6 WORM PINION GEAR
7 SNAP-ACTION SWITCHES

Figure 6—157. Interrupter Assembly.

Snap-action Switches. (Figure 6-157.) The actuators on the snap-action switches (7) are normally disengaged and their points do not touch the cam drum. When one of the actuators runs over a steel cam (1) the switch is actuated, breaking the firing circuit causing the guns to stop firing. As the guns turn in azimuth, the switch carriage rotates correspondingly. As the guns move in elevation, the switch carriage and micro switches move correspondingly. The upper cam and upper switch interrupt the fire of the two right guns. The lower cam interrupts the fire of the two left guns as required.

Collector Assembly. (Figure 6-158.) The purpose of the collector ring assembly is to provide a means of introducing power to the turret to permit full rotation of the turret without twisting the cables. This assembly includes a collector ring (4) a housing, a brush base assembly (5), and a junction box for outlet connectors. The collector ring consists of silver-plated brass rings which are separated by plastic spacers. Wires are soldered to the inside of the collector rings and are brought through the core of the collector ring assembly to a large master electric connector (9) on the bottom of the interrupter and collector as-



1. TERMINAL BOARD
2. AZIMUTH DRIVE
3. BRUSH HOLDER ASSEMBLY
4. COLLECTOR RING ASSEMBLY
5. BRUSH ASSEMBLY
6. CAM DRUM
7. SWITCH CARRIAGE ASSEMBLY
8. SNAP-ACTION
9. MAIN CONNECTOR
10. BRUSH HOUSING SWITCHES

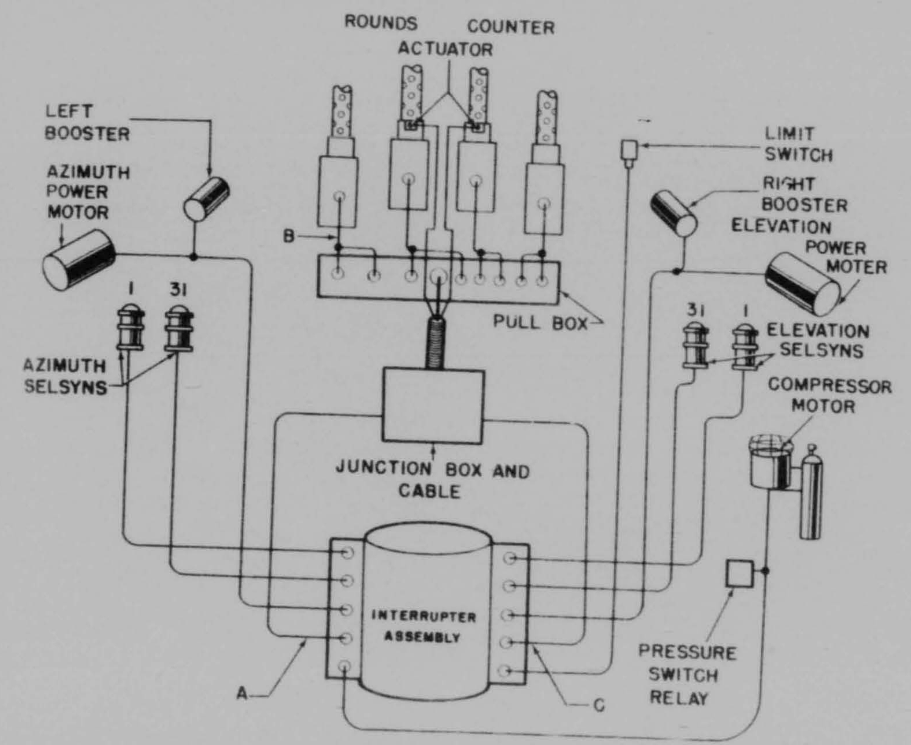
Figure 6—158. Cutaway View of Collector Assembly.

sembly (4). This connector is in turn connected to incoming wires from the control box. It is necessary to keep the position of the collector-ring assembly fixed with reference to the airplane in order to prevent the incoming leads from becoming twisted. This is accomplished by bolting the collector assembly to the cam drum (6) which remains in a fixed position relative to the airplane.

Brush Housing. (Figure 6-158.) The brush housing (10) is used to mount the carbon-silver alloy brushes (5) which ride on the collector rings (4). The top plate rotates with the turret and the housing is attached to the top plate. The brushes are attached to the housing and also rotate with the turret. Wires running from the brush terminals are brought through the top of the collector to ten connectors. Five connectors are located on each side of the interrupted and collector assembly.

Distribution Cables and Boxes

(Figure 6-159.) Power and control are introduced into the turret by the interrupter and collector assembly. All cables lead from the ten connector plugs located on the side of the interrupter assembly to the various electrical components throughout the turret.



A. Cable to left-middle rounds counters and all gun chargers

B. Cable to gun heaters and chargers

C. Cable to right-middle rounds counters and all gun heaters

Figure 6—159. Schematic Diagram Showing Distribution Cables and Boxes.

Cables are of the flexible type with drain holes for condensation.

2. TAIL TURRET

General

The tail turret is located at the rear of the airplane's fuselage. The tail turret is supplied by the Boeing Aircraft Company, except for the elevation- and azimuth-drive assemblies, gun chargers and ammunition rounds-counter actuators, which are manufactured by the General Electric Company.

Description

(Figure 6-160 and 6-161 through 6-163.)

Armament. Two cal. .50 machine guns.

Limits of Tail-turret Movement. (Figure 6-162). The tail turret moves in elevation and in azimuth. The guns can be raised to a maximum of 30 degrees above the horizontal position and can be depressed to a maximum of 30 degrees below horizontal. The limits of azimuth travel are 30 degrees on each side of the straight-aft position. The guns are so mounted that they move as a unit in azimuth and elevation.

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Basic Parts of Tail Turret

- Ring Support
- Dome Support
- Saddle
- Limit Stops and Switches
- Azimuth Drive Assembly
- Elevation Drive Assembly
- Ammunition Feed Assemblies
- Air Compressor System (not mentioned on turret)
- Guide Chute
- Cover
- Dust Cover
- Ammunition Rounds-Counter Actuators
- Gun Heaters

Detailed Description of Tail Turret

(Figures 6-163 and 6-162.)

Ring Supports. The ring support (Figure 6-162) is of welded tubular construction. At the top and bottom of the ring are the bearings which support the gun cradle. The dome support is bolted to the forward side of the ring. Welded to the rear side are clips which mount Dzus fasteners for installation of the fairing hood.

Dome Support. (Figure 6-161.) The dome support is a magnesium casting which is bolted to the forward side of the supporting

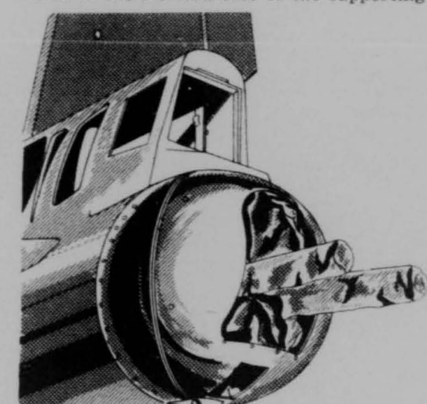
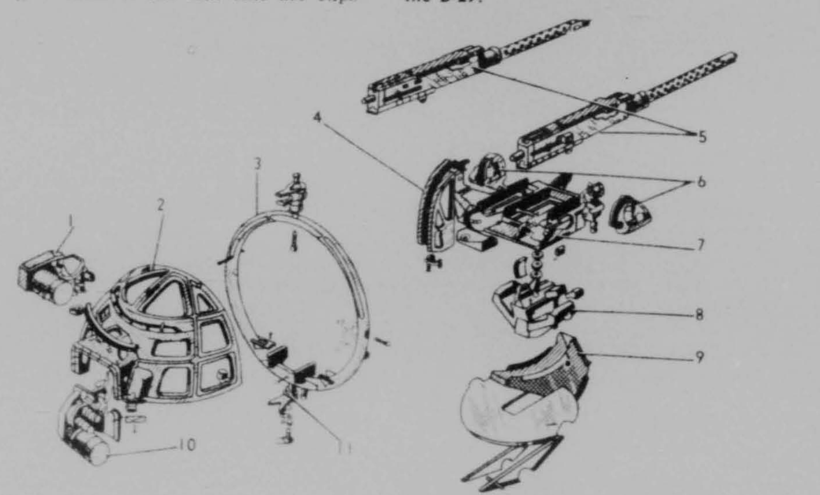
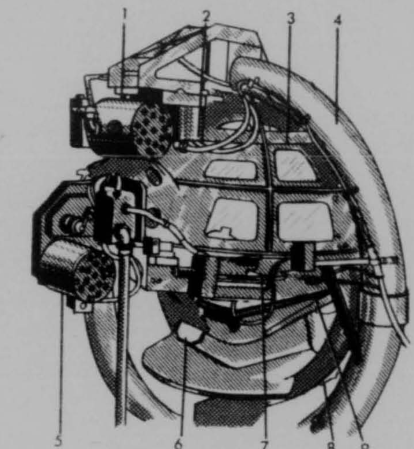


Figure 6—160. The Tail Turret (Stinger) on the B-29.



1. AZIMUTH DRIVE ASSEMBLY
2. DOME SUPPORT
3. RING SUPPORT
4. ELEVATION GEAR SECTOR
5. .50 CALIBER MACHINE GUNS
6. AMMUNITION FEED ASSEMBLIES
7. SADDLE
8. MOVABLE GUIDE CHUTE FOR SPENT AMMUNITION
9. STATIONARY CHUTE FOR SPENT AMMUNITION
10. ELEVATION DRIVE ASSEMBLY
11. LOWER BEARING

Figure 6—161. Exploded View of Tail Turret.



1. AZIMUTH DRIVE ASSEMBLY
2. AZIMUTH GEAR SECTOR
3. DOME SUPPORT
4. TEST SUPPORT FIXTURE
5. ELEVATION DRIVE ASSEMBLY
6. GUIDE CHUTE
7. MACHINE GUN
8. RING SUPPORT
9. SADDLE

Figure 6—162. Fully Assembled Tail Turret.

ring. The elevation-drive mechanisms (Figure 6-161) (10) is mounted to the dome support (2); it drives an elevation-gear sector (4) on the saddle. Azimuth limit stops are mounted on each side of the dome support, and actuate micro switches mounted on the fuselage-frame station 1194. An azimuth-gear sector (Figure 6-162) (2) is also bolted to the dome.

Saddle. (Figures 6-161 and 6-163.) The saddle mounts the two cal. .50 Browning M2 machine guns (Figure 6-163) and ammunition case, feed-roller assemblies (Figure 6-163 [3 and 6]), and the guide chute (Figure 6-161 [6]) for empty shells and links. The saddle is mounted to the ring support (Figure 6-163 [2]) by two trunnion bolts, which allow elevation motion of the guns. The elevation gear sector is mounted to the saddle, and is driven up and down by the elevation-drive mechanism in the dome support. Limit-switch actuators and mechanical rubber limit stops (Figure 6-163) (1), limit the elevation movement of the guns. A cam actuator for operating the elevation stowing-indicators switch is mounted on the left-hand side of the saddle above the trunnion bolt. The machine guns are mounted through a yoke which is bolted to the saddle. Trunnion bolts threaded into the recoil adapter secure the guns to the yoke. The rear of the gun is secured by slider mount bushings, which are also bolted to the saddle.

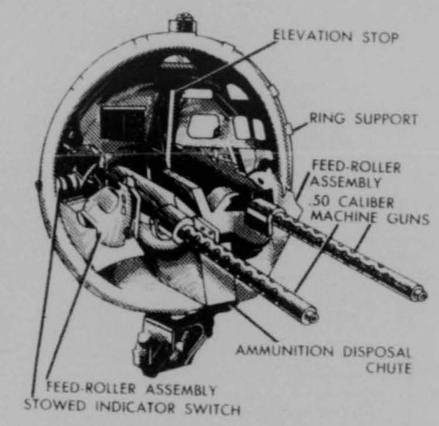


Figure 6—163. Tail Turret with Cover Removed, Rear View.

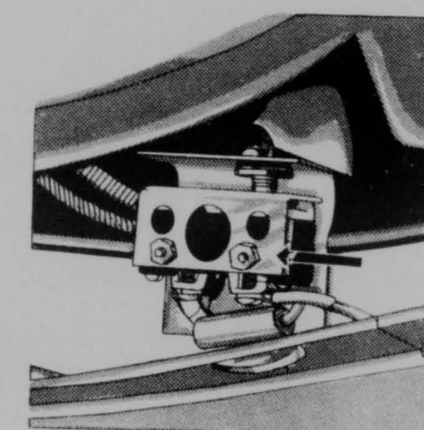


Figure 6—164. Azimuth Limit Switch (One of Two).

Limit Stops and Switches.

Azimuth Stops and Switches. (Figure 6-162 and 6-164.) Aluminum stops with rub-

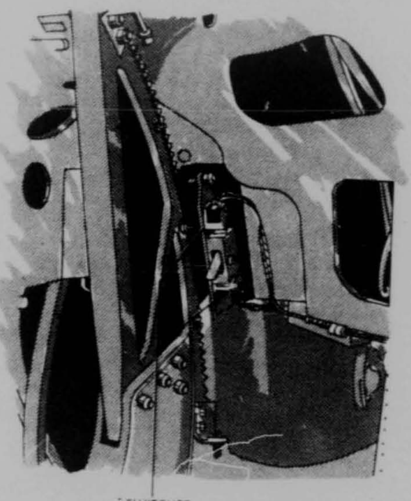


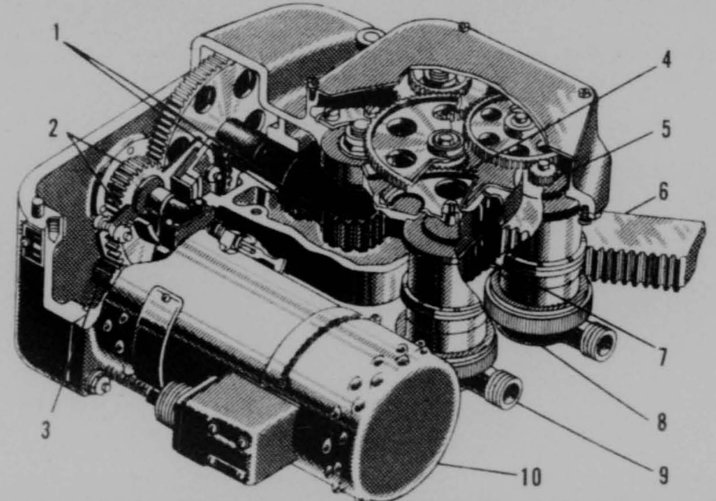
Figure 6–165. Elevation Limit Switches.

ber bumpers are mounted on the dome supports for limiting azimuth motion of the tail turret. These stops allow maximum travel of 30 degrees on each side of the center position. The azimuth limit switches are mounted on fuselage-frame station 1194 and are actuated by cams mounted on the dome.

Elevation Stop and Switch. (Figure 6-165.) The fixed-elevation limit stop is contained within the elevation drive unit and is engaged by limit stops on the left-hand side of the elevation gear-sector supports. These stops limit elevation travel to a maximum of 30 degrees above and 30 degrees below horizontal. The two elevation limit switches (for upper and lower limits) are mounted on the elevation drive assembly and are actuated by two brackets mounted on the right-hand side of the elevation gear sector.

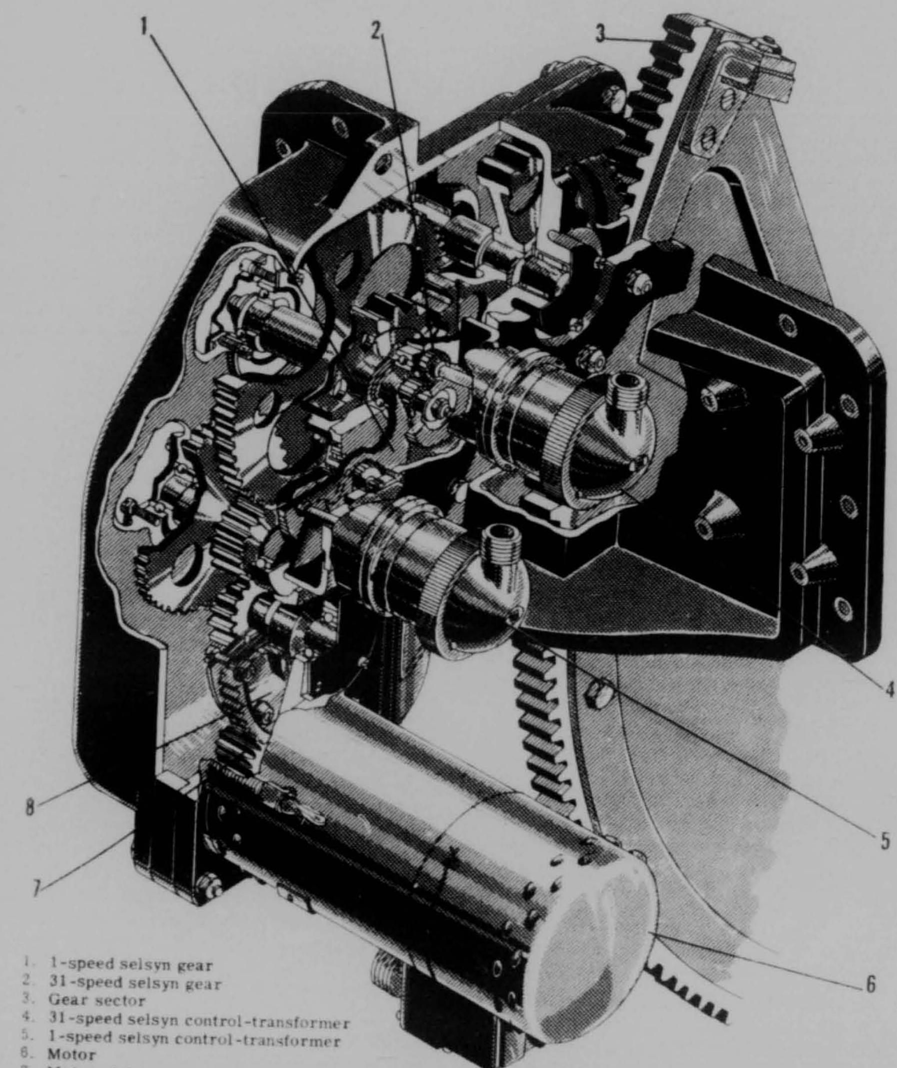
Azimuth Drive Assembly. (Figure 6-166.)

General. The azimuth-drive assembly performs two functions: first, it supplies the mechanical power required to drive the tail turret guns in azimuth; second, it provides electrical equipment to indicate the azimuth



1. Bevel gear assembly
2. Clutch assembly
3. Motor pinion
4. 1-speed selsyn gear
5. 31-speed selsyn gear
6. Gear sector
7. Pinion drive gear
8. 31-speed selsyn control-transformer
9. 1-speed selsyn control-transformer
10. Motor

Figure 6–166. Azimuth Drive Assembly, Three-Quarter Cutaway View.



1. 1-speed selsyn gear
2. 31-speed selsyn gear
3. Gear sector
4. 31-speed selsyn control-transformer
5. 1-speed selsyn control-transformer
6. Motor
7. Motor pinion
8. Clutch assembly

Figure 6–167. Elevation Drive Assembly, Three-Quarter Cutaway View.

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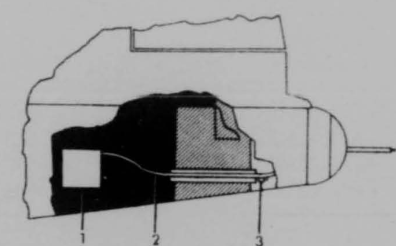
position of the guns. This drive assembly moves the guns to a maximum of 30 degrees to the right and 30 degrees to the left of the straight-aft position.

Function. (Figure 6-166.) The tail-turret azimuth drive assembly includes a motor (10), two Selsyns (8 and 9), and the necessary gearing—including a friction clutch (2). The motor drives through the friction clutch to the drive pinion (7), which mates with the azimuth gear sector (6) on the gun mount. This brings about a speed reduction of approximately 800:1 between the motor and the guns. Also driven from the drive pinion shaft are the 1-speed and 31-speed Selsyn control-transformers (8 and 9). A friction clutch (2) protects the gear train from excessive shock when the guns reach their azimuth limit. A limit switch and limit stops are provided by the manufacturer of the tail turret. These limit the movement of the turret in azimuth, and cut out the power to the motor when the guns reach their limit of travel. Instead of the latch solenoid which is used on the other turrets, the tail-turret drive motor has a solenoid-operated brake. The solenoid is de-energized when the "AZ-power" switch on the control box is in the "off" position. This causes the brake to engage and hold the motor armature, thereby holding the tail turret in its azimuth position. When the "AZ-power switch is in the "on" position, the solenoid is energized, releasing the brake. The brake is also applied automatically when the sight moves beyond the azimuth limit of the gun mount. This de-energizes the solenoid, engaging the brake and holding the gun against the limit stop. When the sight is moved back within the limits of the gun movement, the brake is automatically released. The brake can also be released manually by means of the brake-release handle.

Elevation Drive Assembly. (Figure 6-167.)

General. The elevation drive assembly performs two functions: first, it supplies the mechanical power required to drive the saddle and guns in elevation; and second, it provides electrical equipment to indicate the position of the guns in elevation. The drive assembly moves the guns a maximum of 30 degrees above and 30 degrees below horizontal.

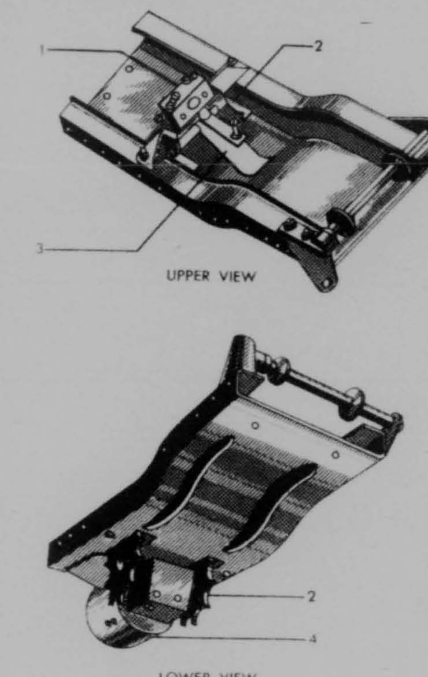


1. AMMUNITION CASE 2. AMMUNITION TRACK
3. SPROCKET-TYPE BOOSTER

Figure 6—168. Ammunition Feed to Machine Guns in Tail Turret.

Function. (Figure 6-166.) The tail-turret elevation drive assembly includes a motor (6), two Selsyns (4 and 5), a limit stop, and the necessary gearing (including a friction clutch, 8). The motor drives through the friction clutch to the drive pinion (7), which drives the elevation gear sector (3) on the saddle. This brings about a speed reduction of approximately 800:1 between the motor and the guns. Also driven from the drive-pinion shaft are the 1-speed and the 31-speed Selsyn control-transformers (4 and 5). Mounted on the elevation drive assembly is a limit stop. When the guns are elevated or depressed to their limits, the stop engages one of the two buffers mounted on the elevation gear sector—stopping the elevation travel of the guns. A friction clutch protects the gear train from excessive shocks when the guns reach their elevation or depression limit. Two limit switches are provided by the manufacturer of the tail turret. They cut off the power to the motor when the guns reach their limit of travel. The elevation motor has a solenoid-operated brake which operates similarly to that described in the preceding column on the azimuth drive assembly. The brake can be released by means of the brake release handle.

Ammunition Cases and Feed Assemblies. (Figures 6-168, 169 and 170.) Ammunition cases for the caliber .50 machine guns are



1. MICRO SWITCH 3. LEVER
2. SPROCKET 4. MOTOR

Figure 6—169. Ammunition Booster for Tail-Turret Machine Gun.

mounted on either side of the fuselage, forward of the pressure bulkhead at station 1110 (Figure 6-170). The ammunition track (Figure 6-168 [2]) is enclosed in a tube as it extends from the case through frame station 1194. A sprocket-type booster (Figure 6-168) (3) in the track pulls the ammunition belt from the case. A (Figure 6-169 [1]) is actuated by a lever, so that when the gun-feed mechanism puts tension on the ammunition belt, the booster will operate, thereby feeding additional ammunition to the gun. When sufficient ammunition is brought up to the gun, the tension of the belt is relayed, thereby shutting down the booster. A feed-roller unit mounted on three bearing rollers, guides the cal. .50 ammunition to the machine gun. As

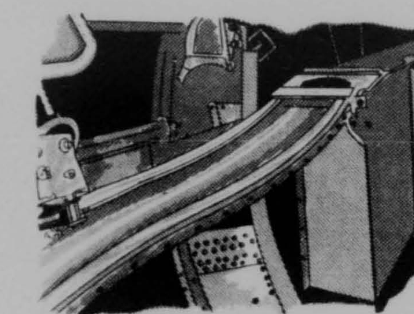


Figure 6—170. Ammunition Case and Ammunition Track Mounted on Fuselage.

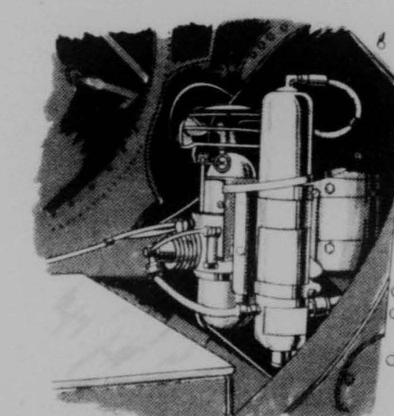


Figure 6—171. Cornelius Tail Compressor Installed.

the guns are raised or lowered in elevation, the feed-roller unit rotates, thus reducing the angle through which the ammunition belt must twist to travel to the guns from the fixed guide rollers at the end of the ammunition track.

Air Compressor System. (Figure 6-171.) The compressor system is the source of supply for the gun charger. The compressor is mounted together with its cylinder on the port side of the airplane, adjacent to the tail gun-

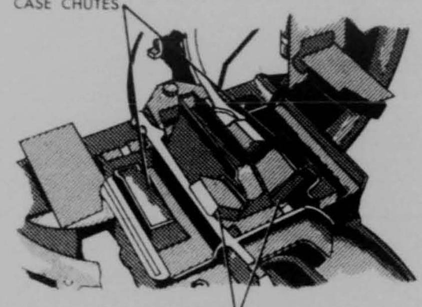


Figure 6–172. Top View of Guide Chute for Tail Turret.

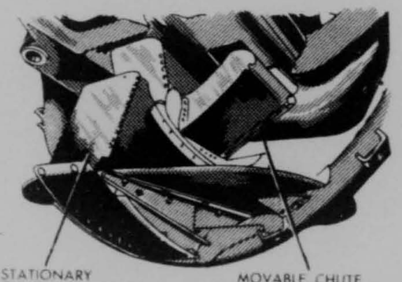


Figure 6–173. Bottom View of Guide Chute for Tail Turret.

ner's compartment. It is similar to the air compressor used on the two-gun turrets which has been described.

Guide Chute. (Figures 6-172 and 6-173.) The guide chute is used to eject the cartridge cases and links from the airplane. It consists of two sections, a stationary chute (Figure 6-173) which is bolted to the support rings, and a movable chute (2) which is composed of two cartridge case chutes (Figure 6-172) and two link chutes. The movable chute is bolted to the cartridge.

Cover. (Figure 6-169.) The cover is a dome-shaped sheet-aluminum fairing. It is Dzus-fastened to the support ring. A vertical open-

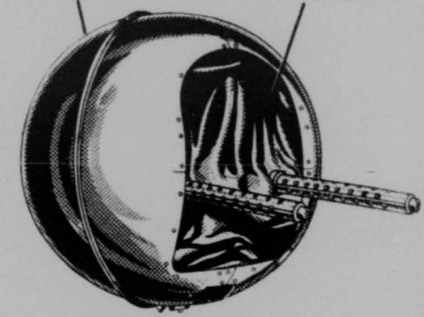


Figure 6–174. Cover Mounted on Tail Turret.

ing allows elevation movement of the cradle and gun.

Dust Cover. (Figure 6-174.) The dust cover, which is made of fabric and fastened to the fairing cover, provides a flexible covering to close off the opening of the dome. A window is provided for the line of sight of the camera.

Ammunition Rounds-counter Actuator. The actuator for the ammunition counter consists of a switch and clamp assembly, and connection cable. The actuator switch is attached with a clamp on the gun adapter so that the face of the actuator is 23/64 of an inch from the gun receiver. The two cables for the actuator switches—left and right guns, come from the junction shield mounted on the elevator drive. The actuator switch is operated by recoil each time the gun fires. When the switch closes, a coil in the counter adjacent to the gunner is energized. The figures indicating reserve ammunition decrease one every time the coil in the counter is energized. The actuators and camera may both be used at the same time without transferring the circuit with a switch on the control box.

Gun Heaters. The gun heaters are connected by two cables from the junction shield mounted on the elevation drive.

3. TURRET ACCESSORIES

Booster System Assembly
(Figure 6-175.)

Boosters are used to assist in the feeding

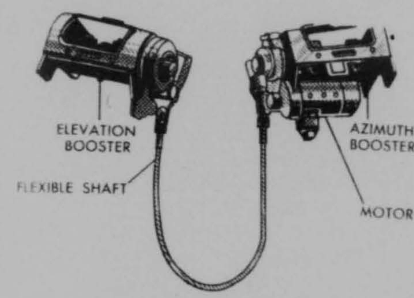


Figure 6–175. Ammunition Booster Assembly.

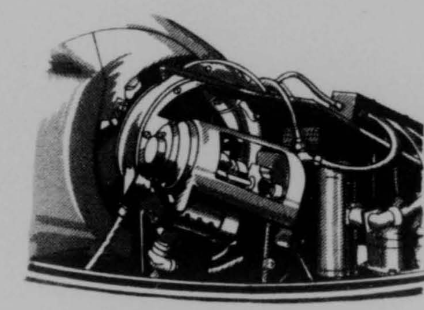


Figure 6–176. Booster Assembly Mounted on Turret.

of ammunition on both upper and lower turrets.

General. (Figures 6-176 and 6-177.) The azimuth booster when installed on the turret, is mounted on the azimuth saddle support, and the elevation booster is mounted on the elevation saddle support. A single electric motor (Figure 6-177) which is part of the azimuth booster, drives the azimuth booster, and by means of a flexible shaft connected to the azimuth booster, it drives the elevation booster. Both boosters include sprockets (17) which engage the ammunition belt in order to feed the belt to the gun.

Function. Since a Browning machine gun relies upon the recoil of the gun to pull the successive rounds of ammunition into the gun, the available pull on the ammunition belt must not be excessive or the gun will be unable to pull the succeeding round in the chamber. The boosters are designed to assist the recoil action of the gun and to insure continuous feeding of the ammunition belts. The booster runs continuously while the firing trigger is depressed. The two boosters are identical except for the motor on the azimuth unit.

Motor. The motor (Figure 6-177) (16) driving the General Electric booster assemblies is a direct-current, series-wound motor operating at 3,800 rpm. This speed is reduced by the gear train of the drive to approximately 140 rpm at the sprockets under normal load.

The sprockets (Figure 6-177) (17) which pull the ammunition belts into the guns are driven by the motor through a reduction gear training a free-wheeling unit (1). The free-wheeling assembly makes possible the rotation of the sprockets for drawing the ammunition into the guns, in the event of motor failure or a locked gear train and thus prevents any interruption of ammunition feeding. Under such conditions, the ammunition belt is fed by the action of the gun itself. The main drive shaft is provided with a brake (5) to prevent the weight of the ammunition belt from turning the booster sprockets backwards and consequently not feeding the guns.

Under normal conditions, the booster will feed the ammunition slightly faster than the gun is able to shoot. During a long burst the belt of ammunition is compressed between the sprockets and the gun and when no further compression is possible, the succeeding rounds ride up and over the sprocket's teeth. Between bursts, the motor is stopped. The row of ammunition between the sprockets and the gun remains under compression, however, thus insuring instant delivery of rounds to the gun when firing is resumed. To prevent the ammunition belt from attempting to turn with the sprockets, a stripper is provided on the bracket assembly (Figure 6-177) (18). Thus, when ammunition is pulled over the sprockets, it is stripped from the sprockets and fed into the gun without jamming ammunition around the sprockets.

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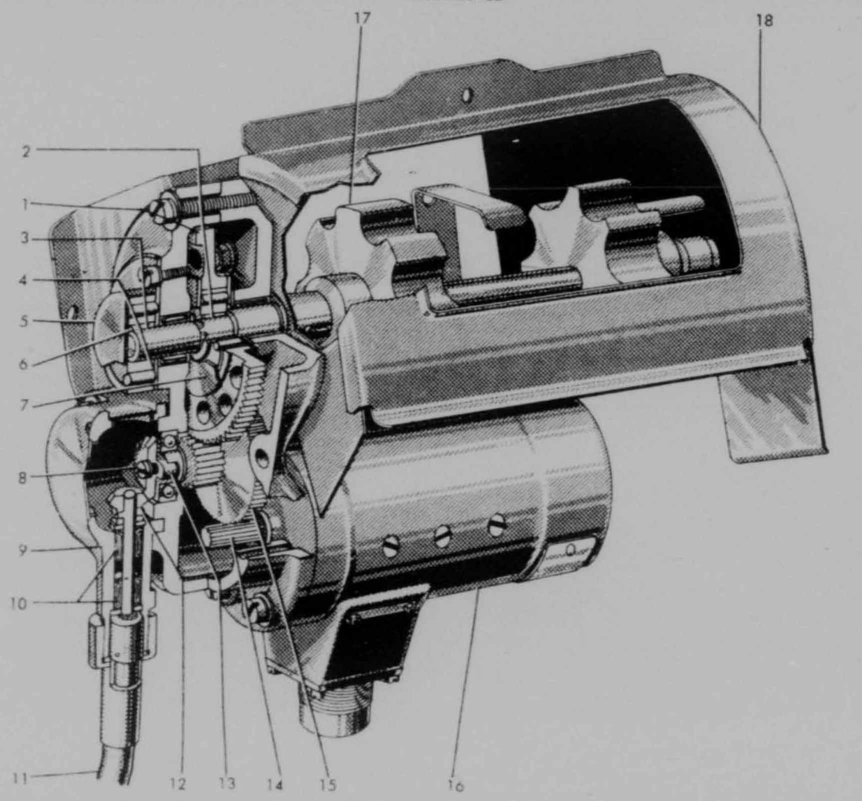


1. FREE-WHEELING ASSEMBLY
2. KEY
3. MAIN SHAFT
4. ROLLERS
5. BRAKE ASSEMBLY
6. KEY
7. GEAR
8. BEVEL GEAR
9. OUTPUT DRIVE
10. NEEDLE BEARINGS
11. FLEXIBLE SHAFT
12. BEVEL GEAR
13. OUTPUT SHAFT
14. PINION GEAR
15. GEAR
16. MOTOR
17. SPROCKET AND SHAFT ASSEMBLY
18. AZIMUTH FEED BRACKET

Figure 6—177. Cutaway View, Azimuth Booster.

4. CONTROL BOXES

General

(Figures 6-178, 6-179, 6-180 and 6-181.) There are four control boxes, one each for the upper- the nose- the blister- and the tail-sighting station positions. The control boxes are made of sheet aluminum and contain electrical devices such as switches, relays, contractors, circuit breakers, capacitors, and resistors. Each box has several AN connectors through which connections are made to other parts of the system.

Location and Function

The boxes are conveniently located so that each gunner can quickly and easily control

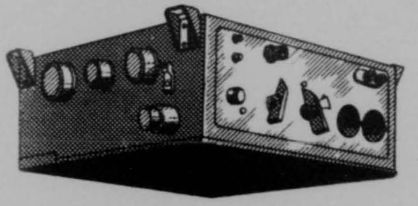


Figure 6—178. Upper Control Box.

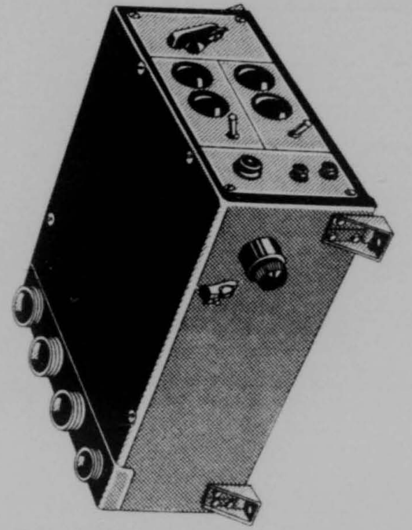


Figure 6—179. Nose Control Box.

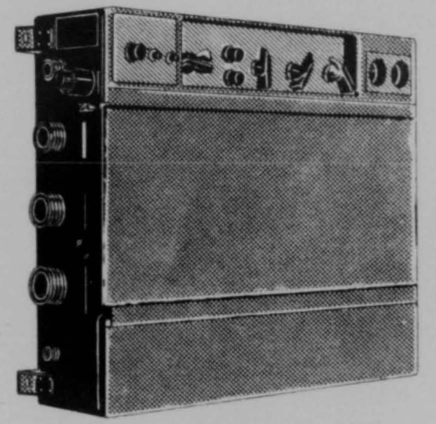


Figure 6—180. Blister Control Box.

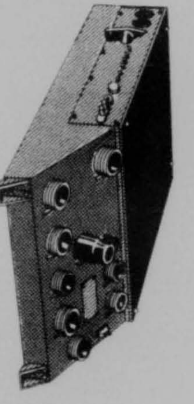


Figure 6—181. Tail Control Box.

and operate the equipment at his command or transfer the control to a gunner at a different sighting station. The nose control box is located at the right side of the nose gunner (bombardier). The upper control box is fastened to the ceiling directly aft of the upper gunner. The blister control box is located aft and between the right and left-blister gunners. The tail control box is fastened to the side of the airplane at the gunner's left.

Components

Because of the similarity in the operations to be performed, several duplicate or similar devices are used in the four control boxes. These are: circuit breakers, switches, contractors, relays, and ammunition-rounds counters. Also each control box has a terminal post for incoming 27-volt DC power and a twin-binding post for obtaining 400-cycle, 115-volt power. No junction box is used with the tail turret; therefore more relays and devices are located in the tail control box than in the other control boxes.

Circuit Breakers. (Figures 6-182 and 187.) Circuit breakers with a thermal-tripping element are used in the main circuits to provide overload and short circuit protection (K500,

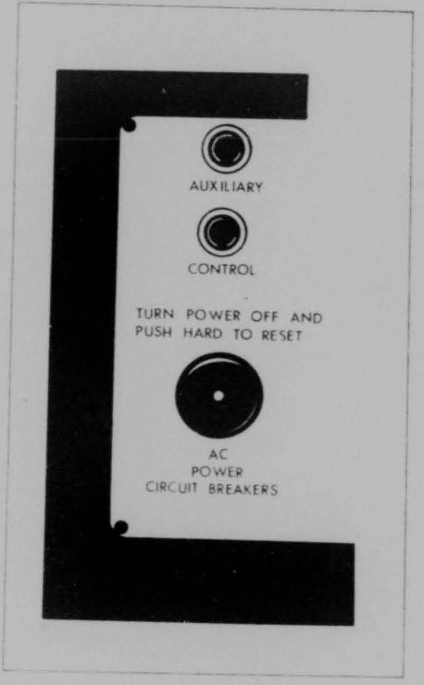


Figure 6—182. Partial View of Control Box Panel Showing Reset Buttons.

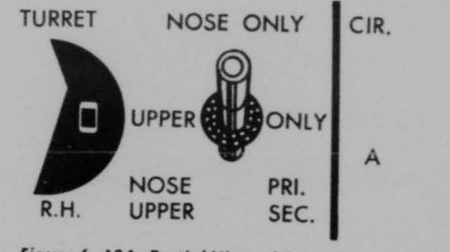


Figure 6—184. Partial View of Control Box Panel Showing Toggle Switch.

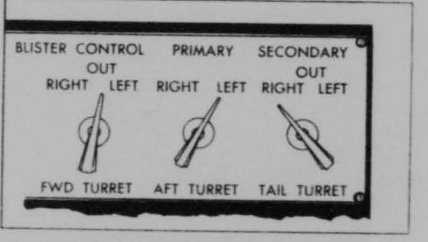


Figure 6—185. Partial View of Control Box Panel Showing Handles of Three Rotary-Type Switches.

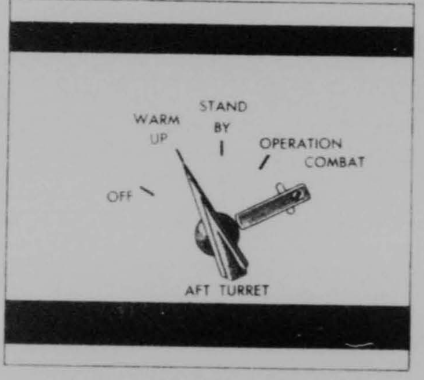


Figure 6—183. Partial View of Control Box Panel Showing Handle of Uni-Switch.

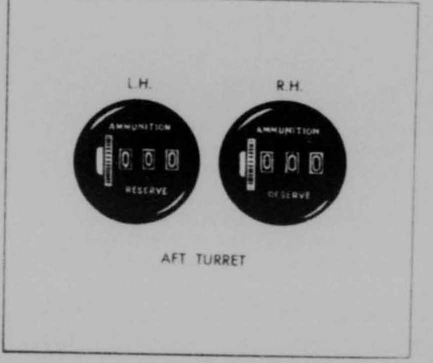
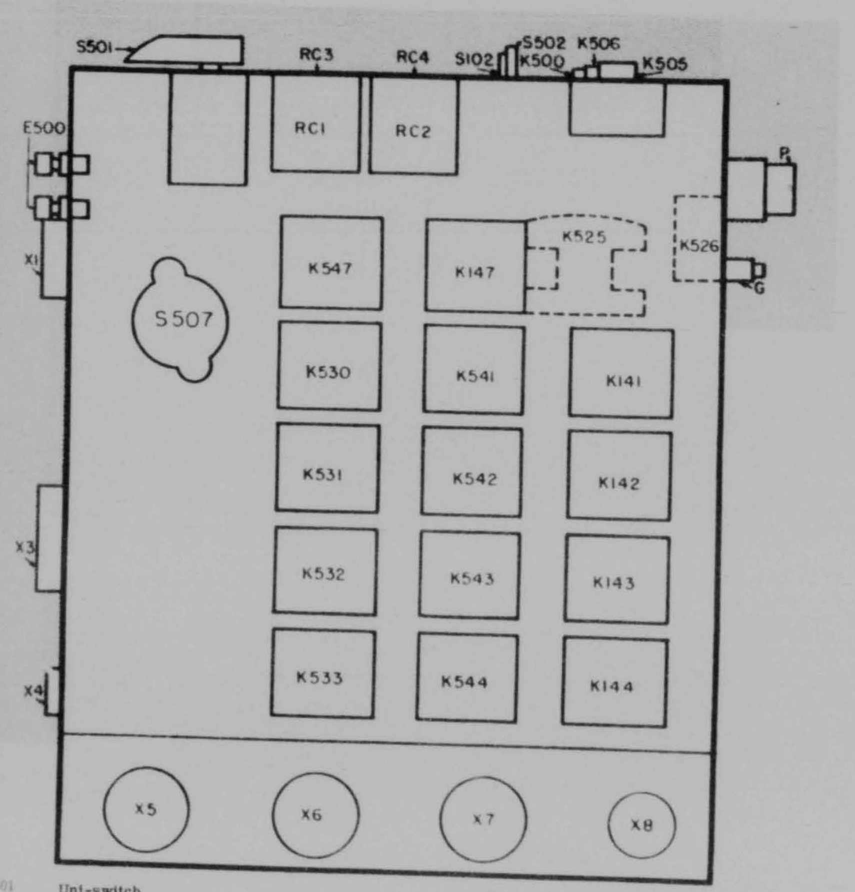


Figure 6—186. Partial View of Control Box Panel Showing Ammunition-Rounds Counters for One Turret.



S501	Uni-switch	X4	Computer connector
S507	Selector-switch	X5	Upper-turret and blister connector
S-507	Conversion switch	X6	Lower-turret connector
X1	Sight contactor	X7	Upper-turret connector
X3	Computer connector	X8	Cynamotor connector

Figure 6—187. Interior View of Nose Control Box.

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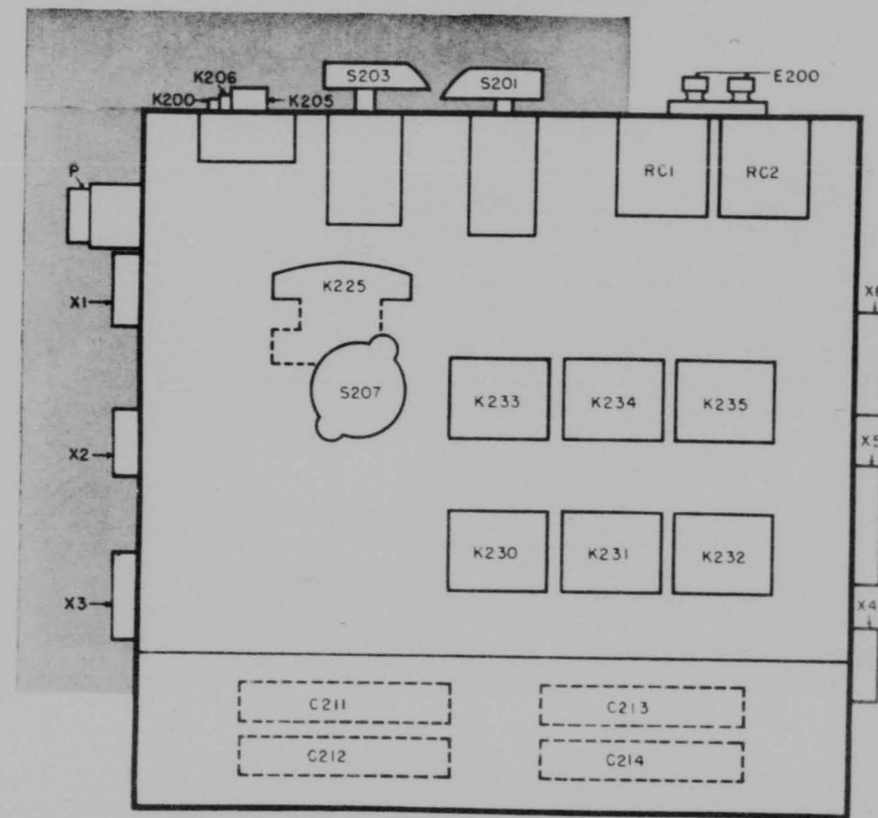

RC2	Right-hand ammunition counter	X2	Dynamotor connector
S201	Uni-switch	X3	Turn
RC2	Right-hand ammunition counter	X2	Dynamotor connector
S201	Uni-switch	X3	Turret-junction-box connector
S203	Selector switch	X4	Computer connector
S207	Conversion switch	X5	Computer connector
X1	Nose connector	X6	Sight connector

Figure 6—188. Interior View of Upper Control Box.

K505 and K506, Figure 6-187). After they are automatically tripped, they are reset by pushing in a reset button. The circuit breakers are of two types, one larger than the other. The larger circuit breaker has ratings of 70 amperes and 120 amperes. The smaller circuit breaker has ratings of 10, 15, 20, 35 and 50 amperes.

Switches. Switches are placed on the control boxes for operating the turrets or for circuit selection.

Uniswitch. (Figures 6-183 and 6-187.) A five-position uniswitch is placed on each control box (S501, Figure 6-187). The switches simplify the operation of the turrets. The

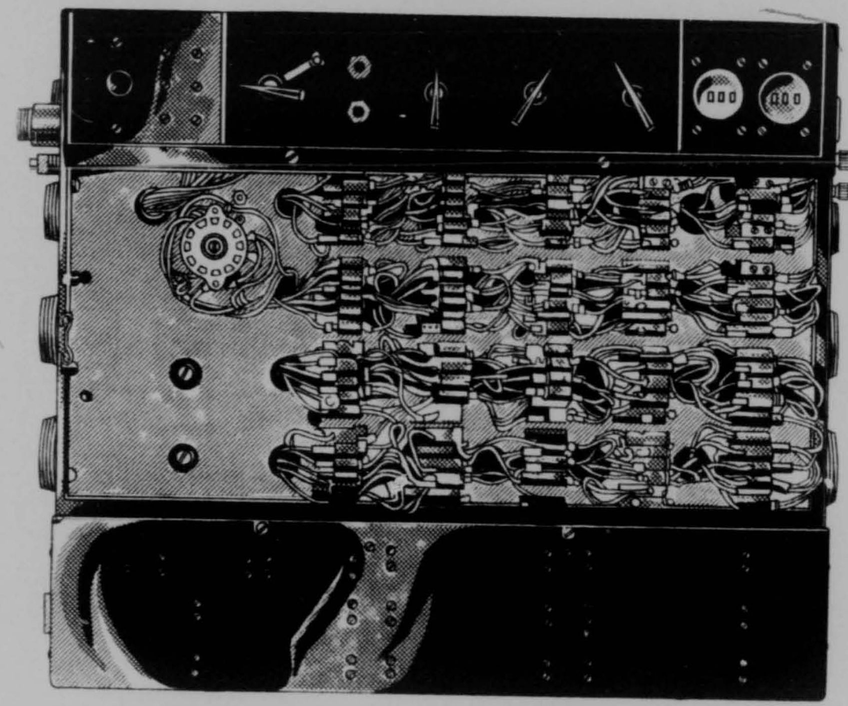

Figure 6—189. Interior View of Blister Control Box.

five positions control the five steps in the operation, which are as follows: "Off," "warm-up," "standby," "operation," and "combat" (Figure 6-183). The switch consists of switchettes so arranged that they are operated from cams. The cams rotate as the switch handle is turned from one position to another position.

Selector Switches. These switches are of the toggle type having three positions (Figure 6-184) or of the rotary type having either two or three positions (Figure 6-185).

Conversion Switches. These switches are of the two-position rotary type to be operated by a screw driver. They are set to the "restrained gyro" or "free gyro" position to correspond to the type of computer and sighting station used (S507, Figure 6-187).

Contactors. Contactors are used in the heavy-current circuits to energize and de-energize the circuits (K525, Figure 6-187). The contractors are single-pole, single-throw, double-break and are of two types, one larger than the other. The large contactor has a rating of 200 amperes and the smaller contactor has a rating of 50 amperes. Each contactor has a normally open contact which closes when its coil is energized.

Relays. Relays are used in the control boxes to energize and de-energize the various circuits to perform nine different functions.

Computer In-out Relays. In the blister control box (Figure 6-189) four-pole, double-throw relays are used to cut the computer in and out of service. In the other three control boxes, a three pole double-throw relay is used for this purpose.

Transfer Relays. The transfer relays are identical to the computer in-out relays. The

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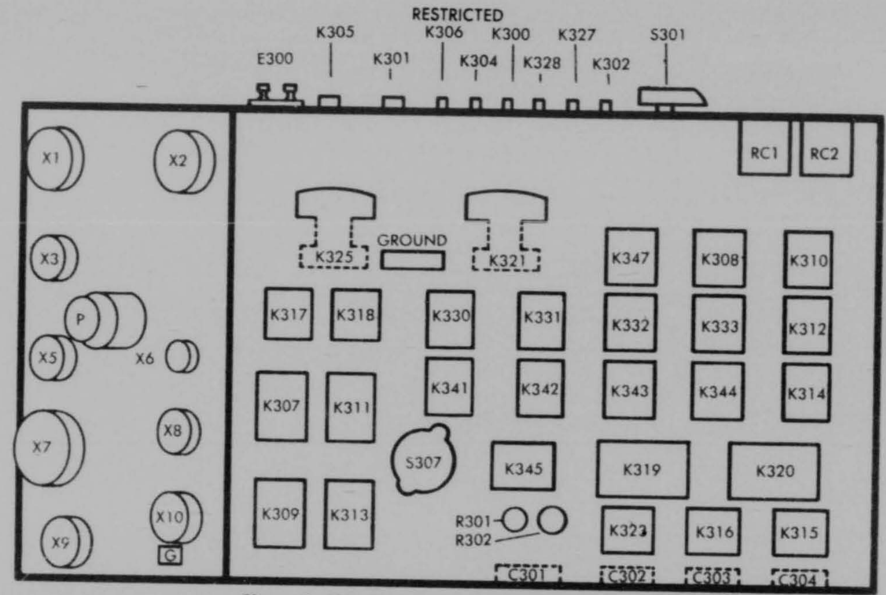

Figure 6—190. Interior View of Tail Control Box.

blister control box has four-pole double-throw relay while other control boxes have three-pole, double-throw relays (K141, Figure 6-187) for this purpose.

Field Relays. These are double-pole, double-throw relays, used in the tail control box (K307, K309, K311, and K313, Figure 6-190) for energizing the fields of the two amplidynes.

Elevation-limit Relays. These are three-pole, double-throw relays, used in the tail control box (K312 and K314, Figure 6-190) to limit the elevation motion of the tail turret.

Azimuth-limit Relays. The azimuth-limit relays are identical to the elevation-limit relays, and are used in the tail control box (K308 and K310, Figure 6-190) to limit the azimuth motion of the tail turret.

Backout Relays. These are differential-current double-coil relays located in the tail control box (K319 and K320, Figure 6-190). They are three-pole, single-throw relays. Their purpose is to provide circuit connections for moving the tail turret off of the limit switch after the azimuth or elevation limit switch has operated.

Action Relay. This is a four-pole, double-throw relay, used in the tail control box (K345, Figure 6-190).

Out of Synchronism Fire Interruption Relays. These are single-pole, double-throw differential-current relays, used in the tail control box (K317 and K318, Figure 6-190).

Time-delay Relay. This is a single-pole, double-throw relay located in the nose control box (K526, Figure 6-187). Time delay is obtained by a thermal element. The time-delay action prevents the starting of all four amplidynes at the same time.

Ammunition-rounds Counters. (Figure 6-186.) There are two ammunition-rounds counters (Figure 6-186) for each turret and they are located in the control box where the gunner has primary turret control (See RC1 and RC2, Figure 6-187). Therefore each control box has two ammunition-rounds counters except the nose control box which has four to take care of the upper-forward and lower-forward turrets.

Capacitors. Capacitors are used in the upper and the blister control boxes for the

purpose of power-factor correction and in the tail control box for stabilizing purposes. Four are used in the upper control box (C211, Figure 6-188), and four in the tail control box (C301, Figure 6-190).

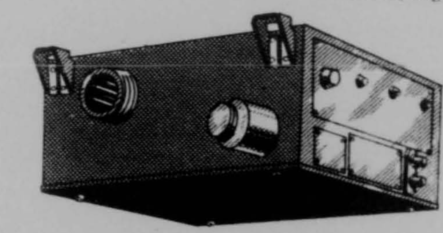

Figure 6—191. Typical Turret Junction Box.

Resistors. Two small resistors are used in the tail control box (R301 and R302, Figure 6-190). One is an azimuth grounding resistor and the other is an elevation grounding resistor.

Indicator Lights. One indicator light is placed on the upper control box, and two are placed on the blister control box (I302 and I502, Figure 6-180). Each light indicates to the gunner when a particular turret is being operated by the gunner having primary control of the turret.

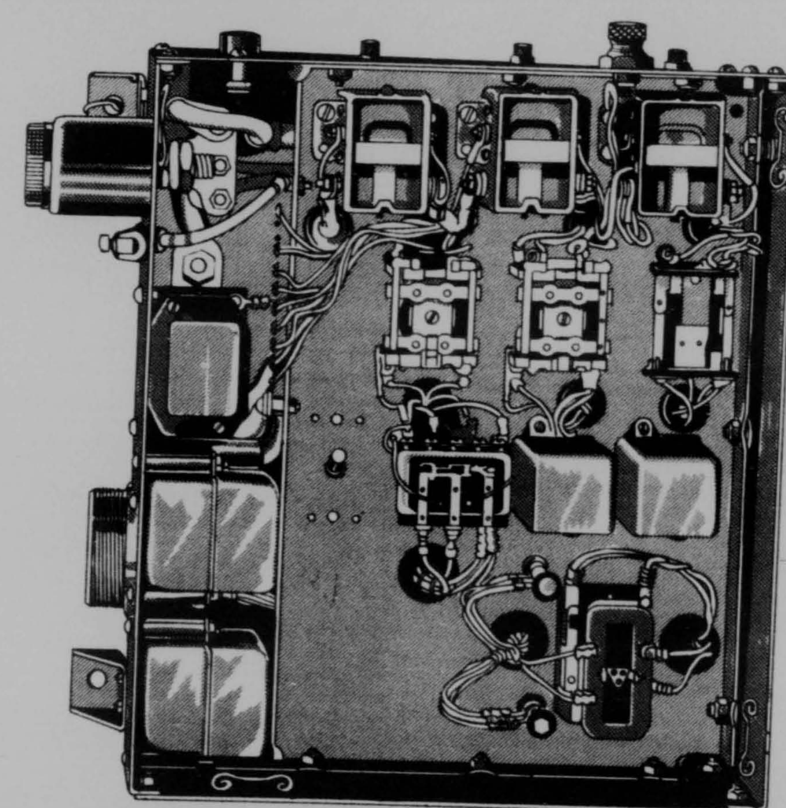

Figure 6—191A. Interior View of Typical Two-Gun Turret Junction Box.

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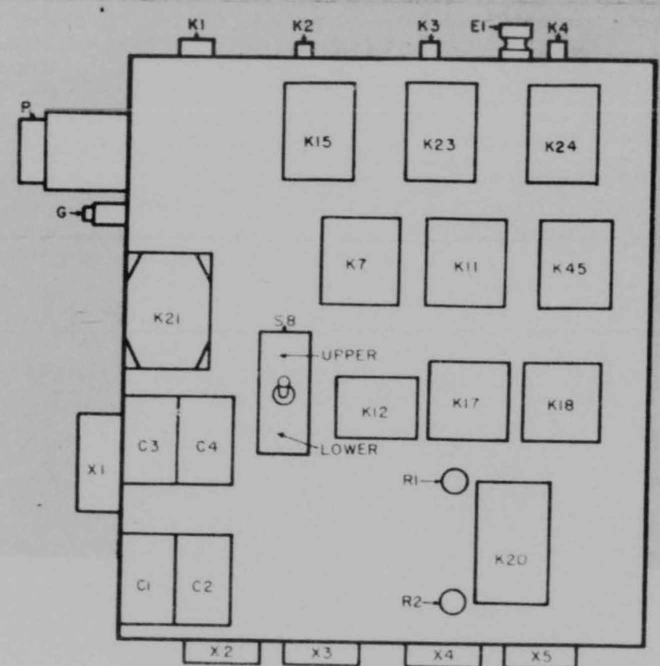

Figure 6—192. Interior Diagram of Typical Two-Gun Turret Junction Box.

Nose Control Box
(Figure 6-187)

This box is located at the right side of the nose gunner (bombardier).

Upper Control Box
(Figure 6-188)

This box is fastened to the ceiling directly aft of the upper gunner.

Blister Control Box
(Figure 6-189)

This box is located aft and between the right and left-hand blister gunner.

Control Box
(Figure 6-190)

This box is fastened to the side of the airplane at the gunner's left.

5. JUNCTION BOXES
(Figure 6-191 and 6-191A)

Four junction boxes are used in the remote-control turret system, one for each of the turrets except the tail. The junction boxes house such electrical devices as capacitors, circuit breakers, relays, contactors, and resistors. All junction boxes for the two-gun turrets are identical. The junction box for the four-gun turret differs from those for the two-gun in some interior details.

Location

The junction boxes are located within the

pressurized areas of the airplane so they can be reached during flight for resetting of the circuit breakers. The upper-forward turret junction box and the lower-forward turret junction box are located to the right of the forward turrets. The upper-aft-turret junction box is mounted under the control box of the upper sighting station. The lower-aft-turret junction box is located forward of the lower-aft turret.

Components
(Figure 6-192)

Circuit Breakers. Four thermal-overload circuit breakers are located in each junction box (K1, Figure 6-192) : a 120-ampere turret-power circuit breaker (K2), a firing-power circuit breaker (K3), a 35-ampere auxiliary-power circuit breaker, and (K4), a 15-ampere turret-control circuit breaker. The firing-power circuit breaker in the two-gun turret junction box is rated 35 amperes, and the firing-power circuit breaker in the four-gun turret junction box is rated 50 amperes. The circuit-breaker reset buttons extend through the side of the junction boxes where they can be reached for resetting.

Relays. Relays are used in the junction box to energize and de-energize circuits to perform five different functions.

Field Relays. These are double-pole, double-throw relays used in the junction boxes to control power to the azimuth and elevation amplidyne control fields (K7 and 11, Figure 6-192). One set of contacts of the elevation field relay is used in connection with control of power to a backout relay.

Elevation Limit Relay. This is a three-pole, double-throw relay (K12, Figure 6-192) used in each junction box. It is connected in the firing-contactor circuit and also in the holding and stowing circuits in the two-gun turret junction box.

Elevation Backout Relay. This is a double-pole, differential-current relay (K20, Figure 6-192) used in the two-gun-turret junction boxes. It permits backout of the turret after the elevation amplidyne field relay has interrupted power from the servo-amplifier to the amplidyne control field. A three-pole, differential-current relay in the four-gun-turret junction box performs the same function. The third pole operates the motor brake.

Action Relay. This is a four-pole, single-throw relay (K45, Figure 6-192).

Out-of-synchronism Fire-interrupter Relays. These are differential-current relays (K17 and K18, Figure 6-192) used in the junction box to serve as azimuth and elevation out-of-synchronism fire interrupters. A normally closed set of contacts in each relay interrupts the firing circuit whenever the servo-amplifier outputs are sufficiently unbalanced.

Contactors. Contactors are used in the junction boxes to energize and de-energize circuits to perform four different functions.

Auxiliary-power Contactor. (K23, Figure 6-192.) This is a 50-ampere contactor which controls power to the air compressor and gun heaters.

Turret-power Contactor. (K24, Figure 6-192.) This is a 50-ampere contactor which controls power to the drive motor fields, turret latches, and certain operating relays and holding circuits.

Amplidyne Contactor. (K21, Figure 6-192.) This is a 200-ampere contactor used for starting the two turret amplidynes. Coil-shorting contacts in the unit permit temporary high coil currents to be used for pull-in of the armature.

Firing Contactor. (K15, Figure 6-192.) The firing contactor is a 50-ampere single-pole, single-throw contactor which controls power to the gun-charger firing solenoids.

Stabilizing Capacitors and Resistors. (C1, C2, C3 and C4, Figure 6-192.) Four stabilizing capacitors and two associated grounding resistors are located in each junction box. Two of the capacitors and one resistor are connected in each amplidyne output circuit.

Stowing and Holding Resistors. In the two-gun-turret junction boxes, two resistors not found in the four-gun boxes are mounted close to the limit relay. One of the resistors (Figure 6-192) is known as a stowing resistor since it is used in the turret-stowing circuit. The other is known as a holding

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resistor since it is used in the circuit which holds the guns in stowed position while power is on but the turret is not being operated.

Upper-lower Turret Switch. (S8, Figure 6-192.) This is a three-pole, double-throw switch which is mounted in the two-gun-turret junction box to permit shifting the circuits of the box to adapt it for use with either upper or lower turrets. This switch is concealed when the cover of the box is in place so that it will not be inadvertently thrown to the wrong position after the box is once installed. It should be safety-wired in the proper position when the box is installed.

Terminal Posts and Connectors. The junction boxes are provided for a terminal post (P, Figure 6-192) for incoming 27-volt DC power and with a twin-binding post (E1) for obtaining 400-cycle, 115-volt power. They are provided with AN connectors for connection with other circuits.

SECTION VI—SERVO AMPLIFIER

1. PURPOSE AND NOMENCLATURE

The servo amplifier is an electronic device used in the remote-control turret system. It consists of vacuum tubes, transformers, and other elements necessary in an electrical circuit for amplification and rectification of an electrical signal.

Function

In the follow-up system the servo amplifier is located between the Selsyn system which furnishes the error signal, and the amplidyne generator which generates the power for the armature of the turret drive motor. It is so located because it has 4 functions:

It must amplify the error signal so there will be sufficient power in the control field of the amplidyne to secure full amplidyne output.

It must change the AC error signal to DC for energizing the control field of the amplidyne.

It must provide a method of changing from the 31-speed to the 1-speed error signal when the sight and turret are more than three degrees out of alignment and of reverting to the 31-speed signal when the turret and sight have been brought to close alignment. As previously explained, a misalignment between the sight and turret causes an AC signal output from the Selsyn system. This output, which is an AC voltage, regulates the amount of DC flowing in each half of the control field of the amplidyne. The amplidyne output in return, causes the turret-motor armature to rotate which drives the guns into alignment with the sight. The servo amplifier is the unit to which these small AC voltages are used to control direct current large enough to excite fully either one half or the other of the amplidyne control field. The servo amplifier regulates the current in each half of the control field of the amplidyne.

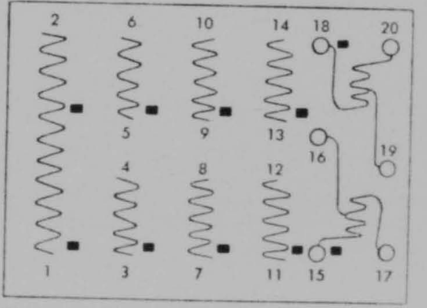

Figure 6—193. Power Supply.

It must provide a bi-directional output depending on the direction of movement of the sight.

Azimuth and Elevation Channels

The servo amplifier is really two amplifiers in one, because two motions, azimuth and elevation, must be controlled independently. It is customary to call these independent parts of the amplifier "channels" and to speak of the azimuth channel and the elevation channel. A power transformer is shared by the two channels, but there are independent secondary windings for each channel. This power transformer, referred to as T-4, is used to supply power to all tubes in the servo amplifier in both azimuth and elevation channels. (Figure 6-193). It consists of a primary winding energized by the 115 volt 400 cycle AC from the dynometer, and eight secondary windings. Four of these secondaries have 275 volts AC potential to be used for plate potential output tubes, two for azimuth and two for elevation; two secondaries of 230 volts AC potential, to supply plate potential for the one-speed tube, and plate potential for the screen grid tube (one of these secondaries for azimuth and one for elevation.) The other two secondaries of 6.3 volts AC potential are used to supply heater voltage for all tubes in the servo-amplifier. One of these 6.3 volt windings supplies heater voltage for all tubes in the azimuth channel and the other 6.3 volt winding for all tubes in the elevation channel. The servo-amplifier makes the distinction of conducting on alternate half cycles, i.e., on one-half of the AC output of the dynamotor the azimuth channel will conduct, and on the other half-cycle the elevation channel will conduct. The T-4 power transformer is so wound that when terminal 2 of the T-4 is negative, the azimuth channel will conduct because, at this time, the plates of all the azimuth tubes will have a positive potential applied. (Figure 6-194). At this same time, the plates of all the

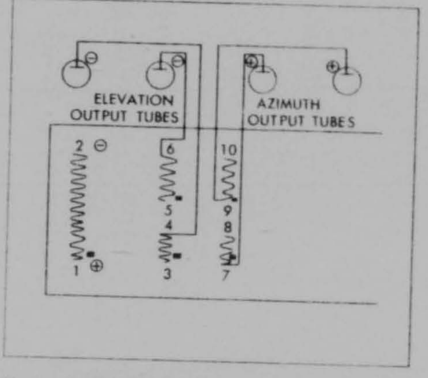

Figure 6—194. Partial Elementary Diagram, Basic Circuit, Elevation and Azimuth Output Tubes.

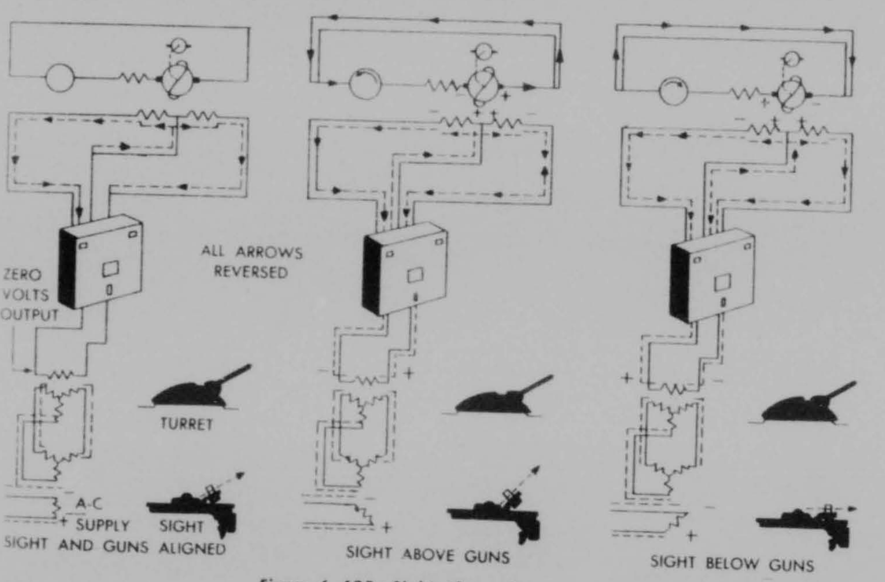

Figure 6—195. Sight Above Guns.

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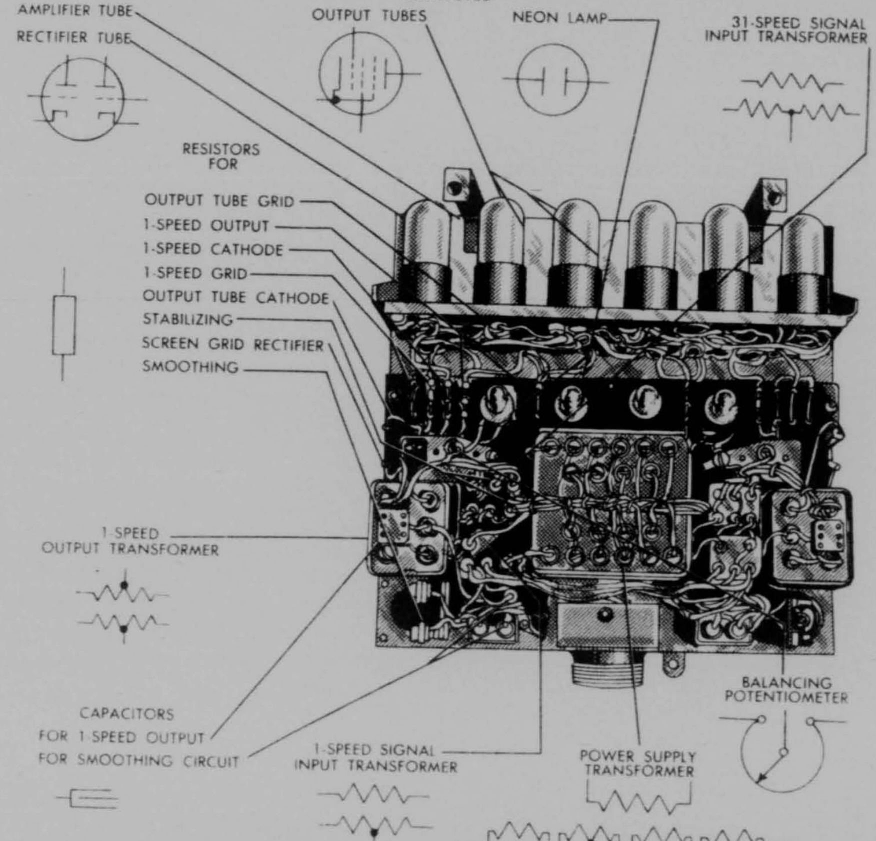

Figure 6–196. Servo-Amplifier, Type 2CV1C1, Interior View, Showing Electrical Symbols for Various Elements.

elevation tubes will have a negative potential, therefore not conducting. On the next half cycle of the dynamotor output, all these polarities are reversed, making the azimuth channel nonconducting, because of a negative potential on the plates of these tubes; but the elevation channel will conduct, due to a positive potential on the plates of its tubes. Since both channels are identical, only the elevation channel, the amplifier for which is located in the half of the case, will be described.

5. ELECTRON THEORY

Although references for this material (T.O. 11-70A-1) use the conventional theory of electron flow, (current flows from positive to negative) this information is written in accordance with the electron theory, (current flowing from negative to positive).

Operation of Electron Theory

Figure 195 shows schematically three possible conditions that might exist in the system. At the left, sight and guns are aligned, the output of both the 1- and 31-speed selsyn control transformer is zero volts and the servo amplifier allows equal currents to flow in the two halves of the amplidyne control field. This

results in no output voltage generated by the amplidyne and no motion of the elevation drive motor, which is as it should be when guns and sight are aligned.

In the center diagram of Figure 195 the sight is shown elevated. The Selsyn system sends a signal to the servo amplifier, indicated as a positive (plus sign) on the sight at a particular instant. Now more current flows in the left half of the amplidyn control field and less in the right half. The amplidyne generates a voltage of such polarity that the turret drive motor elevated the guns to align with the sight.

The diagram at the right of Figure 6-195 shows the situation when the sight is lowered below the guns. Comparing this with the center diagram it is seen that the polarity of the Selsyn signal is reversed the right half of the control field has more current and the left half has less. As a result, the polarity of the voltage generated by the amplidyne is also reversed. And the turret-drive motor now drives the guns down to align with the sight.

6. BASIC PARTS AND DETAILED DESCRIPTION

General

The physical appearance and location of each unit of the servo-amplifier are shown in Figure 6-196, together with the symbols by which the units are represented in the schematics and elementary system diagrams. The AN (Army-Navy) connector and the power supply transformer are at the lower center. The units of the elevation channel are located in the left half and similar units for the azimuth channel are in the right half.

Base

The base is a metal plate with four rubber shock mountings, one near each corner. Three straps riveted to the base serves as a support for the AN-3102-28-17P, 15-pin connector, and the anchor pins engaged by the cover lathes. All other parts are attached to the base by screws, studs or bolts. The tube types to be used in each socket are stamped on the base near the tubes.

Cover

The cover slips over the equipment to protect it. The straps on the base and the ends of the tube shelf, guide the cover into place. Sliding latches engage slot in conical pointed anchor pins attached to the straps on the base, which project through holes in the cover. Fastened to the interior of the cover are two sockets for holding a spare tube of each type used in the amplifier and a clip for a spare neon lamp. Louvres and holes permit a circulation of air to carry off the heat from the equipment. A wiring diagram is cemented to the inside of the cover.

Tube Shelf

The tube shelf contains twelve sockets for the eight 6V6-GT output tubes and the four 6SN-7-GT 1-speed amplifier and screen grid rectifier tubes. The shelf is attached to the base by screws and nuts. The eight 100,000-ohm grid-protective resistors for the output tubes are soldered between the grid tab and an unused tab of the output-tube sockets.

Capacitors

Four 0.5 microfarad, 500 volt DC output smoothing capacitors are fastened to the base of the servo with screws and nuts. They are located at the bottom, two on each side of the connector support. A .0015 microfarad, 500-volt capacitor is soldered across the primary terminals of each of the two 1-speed coupling transformers. A .0015 microfarad 500-volt screen by-pass capacitor is mounted on each of the potentiometer assemblies between the plates of the screen grid tube and its plate load resistor. This is a parallel circuit.

Transformers

The power supply transformer for both azimuth and elevation channels is mounted on the base immediately above the AN connector and is held by nuts on the studs projecting through the base. Symmetrically located on each side of the power supply transformer are the two 31-speed input transformers, the two 1-speed input transformers, and the two 1-speed output transformers. All transformers are attached to the base with studs and nuts.

The 31-speed input transformers may be identified by the two 75,000-ohm stabilizing resistors soldered to their terminals. These are not found on the 1-speed input transformers. The primaries of both types of input transformers are rated 57.5 volts 400 cycles. The two secondaries of each 31-speed input transformer are rated 28.75 volts. The secondary of each 1-speed input transformer is rated 115 volts with a midtap. The primary and secondary of each 1-speed output transformer is rated at 220 volts. Both have midtaps.

Potentiometer Assemblies

Above each transformer group is located a potentiometer assembly attached to the base by two screws with nuts, and a ground post. The 40-ohm potentiometer is mounted upon a bracket attached to the ground post at one end and riveted to an upright resistor-board assembly at the other end. An acorn-nut clamps the potentiometer shaft and covers it to prevent tampering. Adjustment of the potentiometer setting is made with a screw-driver. On each resistor-board assembly are terminals to which are soldered a 36-ohm output tube grid-bias resistor and a 5100-ohm output tube screen-grid-current-limiting resistor. Stacked on each ground post above the potentiometer bracket are three nuts and three terminals all locked by a nut on top. The several connections to ground from parts of the servo-amplifier circuits are soldered to the terminals on the ground posts.

Resistor Bracket Assemblies

At each lower corner, and using two of the DC smoothing capacitor mounting screws, are resistor bracket assemblies each mounting the two 10,000-ohm smoothing resistors. The resistors are clamped between two clips. A rivet also holds resistor base and bracket together. Terminals in the resistor base are soldered to the ends of the resistors.

Resistor Unit Assembly

Across the entire middle of the servo-amplifier is mounted the resistor unit assembly. Three posts support the resistor unit panel on the base. The panel has twenty terminals to which the ten resistors are soldered. Four sockets for the neon lamps are attached to the panel. The two outside resistors for the 1-speed amplifier tubes, at each end are 100,000-ohm grid-protective resistors. The third resistor from each end is a 510-ohm grid-bias resistor for the 1-speed amplifier. The fourth and fifth resistors from each end are 100,000-ohm current-limiting resistors for the 1-speed output.

Connection

All internal connections between the several parts of the servo-amplifier and to the AN connector are made with aircraft wire in accordance with specification AN-J-C-48. Where wires may be grouped they are served into a cable with linen twine. All wires are marked with numbers in accordance with a schedule. Number one is a ground connection. Numbers from 2 to 26 apply to the elevation channel. Numbers from 29 to 52 apply to the azimuth channel.

SECTION VII—ONE AND THIRTY-ONE SPEED CIRCUIT OPERATION

1. INTRODUCTION

A DC power circuit from the airplane generator supplies the dynamotor, the amplidyne drive motor and the field of the turret drive motor. The dynamotor generates alternating current power. 115 volt, 400 cycle AC power from the dynamotor is fed to the motor of the Selsyn generator on the sighting station and to the primary of the power-supply transformer in the servo-amplifier. The Selsyn generator sends the sight position signal over the wires of the Selsyn control transformer on the turret. The sight and guns are aligned and the AC voltage alternations are assumed to be stopped or "frozen" at the half cycle when the tube plates are positive.

The stabilizing circuit is used to overcome the tendency of the guns to overshoot the position of alignment with the sight. For example, when the action switch on the sight is depressed, and the guns slew toward alignment, their progress is so rapid that they tend to overshoot the mark. Upon returning, and unless steps are taken to prevent it, they will again overshoot. Such "hunting" for the alignment position could continue indefinitely. For this reason, a stabilizing circuit is provided.

The central station fire control system is used on several types of aircraft such as the B-26, P-61, B-29 and B-50. There are five sighting stations, four turrets and one tail mount on the B-29, and although one sighting station may control one or more turrets, the electrical connections between any given sighting station and the turret being controlled are essentially the same. The transparent dome of the sighting station, which protects the gunner from the slip-stream of the plane, does not turn when the sighting station turns. The sighting station is within the dome. The gunner sits in the seat and aims the sight, a task which he performs manually. The sight is not power driven; the guns are.

The Selsyn generator is constantly sending electric impulses, or signal voltages, to the turret. These signal voltages indicate the position of the sight, so that the turret is always informed of the position of the sight at any particular instant. The Selsyn control transformer compares the relative position of the sight and the guns. When both are pointing in the same direction, or in alignment, no further action takes place. However, if the gunner should elevate the sight, the value of the signal voltages being sent to the turret would be correspondingly altered. When the Selsyn control transformer compares the position of the sight and turret and finds that they are not in alignment, a signal is sent to the servo-amplifier by the Selsyn control transformer and brings the sight and guns in alignment, both in elevation and azimuth. Then the purpose of the central station fire control system has been achieved.

2. PRINCIPLES OF COMPUTATION

For short ranges, with a stationary gun and a stationary target, a gun can be aimed directly at the target by sighting along the gun barrel. However, as has been discussed, in aircraft practice the ideal condition is seldom met, and the direction of the gun's bore axis must be shifted with respect to the direction of a moving enemy aircraft. To better understand the principles of computation some of the work which has been previously covered will be reviewed briefly at this point. The amount that the gun must be shifted depends upon the forces acting upon the projectile after it leaves the muzzle of the gun, such as windage and gravity, and upon the velocity of the target relative to the gun. If the sight is not mounted on the gun, but is located at a distance from it, as is the case with a remote-control turret systems, the line bore must be further changed to compensate for the **"parallax"** distance.

Computing and Noncomputing Sights

There are two methods used at present for aiming the guns at the target, namely, computing and noncomputing systems. In computing systems, the computer can be switched "in" or "out" of the circuit instantly at the option of the gunner. In a noncomputing system, the line of sight is maintained parallel with the line of bore, and the gunner advances the line of sight from the target position in an amount determined by him from his own experience and judgment.

In a computing system, the line of sight is held on the target by the gunner and the relative position of the guns and the sight is determined by the computing mechanism. The use of the computer eliminates the guesswork on the part of the gunner in estimating range, ballistics, parallax, and lead prediction and leaves him free to concentrate on accurately tracking the target and keeping it aligned in the sight.

Whether a computing or noncomputing system is used, the corrections must be taken into account in order to have the projectile strike the target. In a computing system, one computer is used in conjunction with each sighting station. Each computer makes corrections for ballistics, parallax, and lead. Each of these corrections will be considered separately.

Ballistics

Ballistic correction compensates for the deviation of the projectile from the gun line. This deviation is caused by the wind and force of gravity acting upon the projectile. The total ballistic correction consists of windage, gravity, and range corrections. Windage is the term usually used to designate the effects of altitude, temperature, and airspeed on the path of the bullet. A windage force is caused by the airspeed of the airplane. This is merely the airplane's speed relative to the air. This wind force is applied to the projectile in a direction parallel and opposite to the direction of flight.

In an airplane, the wind is always from the front to the rear, never deviating more than a few degrees from the fore and aft axis of the airplane. If the projectile is fired at zero degrees elevation and straight forward or aft, the projectile is not deviated from the line of bore by the windage force. However, for any other gun position, this force will deviate the projectile from the line of bore toward the rear.

Maximum deviation occurs when the target is broadside; and for any given angle from the center line, it is greater in the two forward quadrants, since the energy of the projectile is lost at a greater rate in these quadrants because of greater resultant windage forces. The windage offsetting correction is always forward in the direction in which the airplane is moving.

The magnitude of the deviation, and hence the correction, depends upon the airspeed, air density, and range. The windage correction increases with an increase in airspeed and range and decreases with increase in altitude. For short ranges involved, the correction is nearly proportional to the range of other conditions constant.

The effect of gravity upon the projectile is to cause it to curve toward the earth. The gravity correction is greatest at more degrees elevation and decreases with the movement of guns away from the "O" position. Gravity acts upon the projectile throughout the entire time of flight, and the gravity correction varies nearly directly with the time of flight.

Range is the distance from the gun to the target. As the range is increased the time of flight of the projectile is increased, which has an effect on all corrections.

Gravity correction increases with the range and is nearly proportional to it insofar as the ranges encountered in the computer are concerned.

Windage correction also increases with range and is nearly proportional to it insofar as the ranges involved in the computer operation are concerned.

In order to calculate the ballistic correction, the computer must obtain azimuth gun position, range, and windage.

Parallax

Parallax correction is the angle between the gun and sight, measured at the target, when the gun and sight are located at different positions on the airplane. Without the parallax correction, the guns would point parallel to the line of sight and would miss the target by the distance between the gun and sight location which is parallax base length. There is no parallax correction when the gun and sight are located at the same point. Parallax position varies for different target positions or range. It is zero for straight forward or straight aft.

The factors affecting parallax correction are elevation and azimuth gun positions, range, and the parallax base length. The parallax correction increases from zero degrees to plus or minus 90 degrees elevation and is greatest at plus or minus 90 degrees. The parallax correction increases as the azimuth gun position from zero degrees to plus or minus 90 degrees and is greatest at 90 degrees and 270 degrees. The correction again decreases as the guns move toward 180 degrees azimuth. The parallax correction for a given azimuth position is changed by the movements of the gun elevation position. The parallax correction increases as the range becomes shorter and decreases as the range becomes longer. The parallax correction increases with an increase in parallax base length. In order to calculate the parallax correction, the computer must obtain azimuth gun position, elevation gun positions, range, and parallax base length.

Prediction

Lead prediction correction is an angular correction. It is the angle at the sight between the present and future position of the target. The correction is necessary to compensate for the movement of the target while the projectile is travelling from the gun to the target. It is the same correction that a hunter makes when he shoots ahead of a flying bird.

Since prediction correction is the angle determined by multiplying the angular velocity by the sight angular velocity, gun position, windage, and range. To determine the prediction correction, it is necessary to predict the future position of the target which is the location of the target at the time the projectile will reach it. The prediction of the future position assumes the path of the target to be essentially a straight line while the time taken by the projectile to travel to a point on that path is determined from known characteristics of the ammunition. The proper gun position is obtained when the target and the projectile reach the same point (future position) at the same time. With the target traveling the same direction and speed as the gunner's airplane, there is no change in the angle of sight and hence no lead prediction is necessary. Thus, only the ballistic and parallax corrections are required. However, if the gunner's plane and target are traveling in the same direction at different speeds or in opposite directions, there is a change in the sight angle, requiring a corresponding lead correction angle or "lead prediction."

In order to calculate the lead prediction correction, the computer must obtain the relative angular velocity of the target or line of sight with respect to the gunner's airplane, range of the target, air density, and ballistics as it affects the time of flight of the projectile.

3. OPERATION OF THE COMPUTER

The computing remote-control system is similar to the noncomputing system in all respects except that a computing mechanism is connected in the electrical signal circuit between the sighting station and the gun turret.

When not in use, the computer has no effect on the signals and the system continues to operate as a noncomputing system. However, when the computer is switched in, the computer automatically makes all computations for ballistics, parallax, and lead prediction and displaces the voltage distribution and polarity of the signal voltage between the sighting station and the gun turret. This displacement is of the necessary amount to aim the gun so that, when the gunner aims his sighting station directly at the target the projectile will strike the target, thus eliminating guesswork by the gunner.

Selsyn Differential Generator

Interposed in the computer, between each Selsyn generator located on the sight and Selsyn control transformer located at the turret and elevation and azimuth input unit in the computer, is a Selsyn differential generator. This is mechanically connected to the elevation total correction unit or azimuth total correction unit so that any elevation total correction or azimuth total correction made by the computer results in a rotation of the differential generator's rotor by an amount proportional to the correction. The rotation of this rotor displaces the voltage distribution of the signal by a proportional amount and so moves the gun turret, and the elevation and azimuth input unit located in the computer, by an additional amount corresponding to the correction.

Switches

Two switches control the use of the computing system. Closing the computer standby switch at the sight energizes the coils of the computer cutout relays. This closes the normally open contacts of these relays and opens the normally closed contacts. This section inserts the computer into the signal system between the Selsyn generators and Seisyn control transformers, allowing the computer to correct the Selsyn signal. Closing the computer switch at the control box supplies power to the two gyro units from the 28-volt DC bus bar. If this has been closed for fifteen seconds, allowing the gyroscopes to come to speed, the computer is ready for instantaneous operation as soon as the "standby" switch at the sight is closed.

The Input Follow-up Systems

There are four input follow-up systems in the computer, one for each signal input, namely: gun elevation, gun azimuth, range, and windage. These four inputs are fed to the computer as electrical signals which are converted into shaft rotations. These rotations act as mechanical inputs to the ballistic and parallax units and the axis converter.

Elevation and azimuth gun positions are obtained from the Selsyn system.

Range of the target is supplied by each gunner to his computer by means of a range transmitter potentiometer in his sight. This potentiometer is varied as the gunner adjusts the range knob of his sight. In the 2CHIL computers, the range input may be switched to either the sight or the radar, as he chooses.

Windage is supplied from the five windage transmitter potentiometers in the navigator's handset.

Thus, three different methods for obtaining a signal voltage are used, one through the use of the 1-speed Selsyn control transformers, another through the use of potentiometers, and the third through the use of a radar receiver. The potentiometers are not so accurate as the Selsyn controls but are simpler and more compact, and are sufficiently accurate for the purposes for which they are used. Selsyn control transformers are employed to obtain signal voltages for gun elevation and gun azimuth follow-up systems, because the gun elevation and gun azimuth input signals can be readily obtained from the Selsyn circuits between the associated sight and gun turret, the voltage at the rotor of the Selsyn differential generators in the computer indicating the gun turret positions in azimuth and elevation. Potentiometers are used to obtain signal voltages for the range and windage follow-up system.

An action switch, located on the sighting station and operated by the gunner, energizes the computer control circuits when it is closed.

The computer corrects for ballistics, parallax, and lead and allows the gunner to concentrate on accurately tracking the target and keeping the correct range adjustment. The ballistic correction compensates for the deviation of the projectile from the line of bore. Parallax correction is the angle between the gun and the sight, measured at the target, when the gun and sight are located at different positions on the airplane. Lead prediction correction is the angle at the sight between the present and future position of the target. These are accomplished by a computing mechanism connected in the electrical signal circuit, between the sighting station and the gun turret. In summation, it should be remembered that computer requires four input electrical signals: gun azimuth, gun elevation, windage, and range.

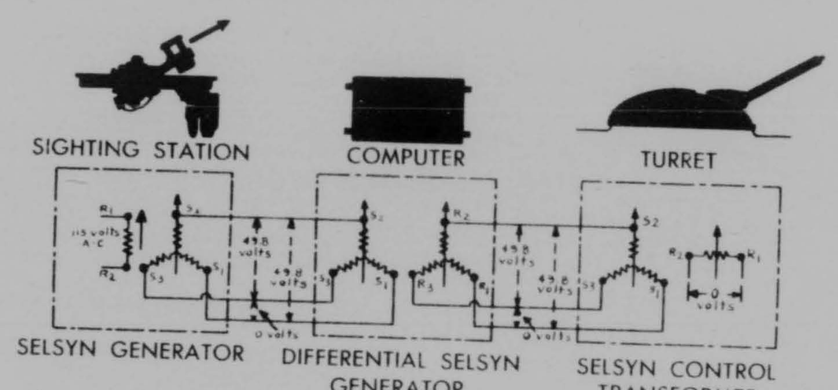

Figure 6–197. Electrical Connections of Differential Selsyn Generator into Selsyn System.

4. DIFFERENTIAL SELSYN GENERATOR USED IN COMPUTING SYSTEM

When the computer is placed in the B-29 fire control system a correction is applied to the Selsyn signal between the sighting station and turret so that the turret does not follow the sight in exact alignment but moves a slightly greater or lesser amount depending upon the corrective signal applied by the computer. For example, if the gunner is tracking an enemy aircraft through the sight, it is desirable to have the turret aim the guns slightly ahead of the target or "lead" the target, so that the target and gun fire will meet in space. The computer will automatically introduce this "lead" correction into the Selsyn system if the gunner simply follows the enemy aircraft with the sight. The correction is introduced by means of a differential Selsyn generator.

The differential Selsyn generator is similar to the standard Selsyn generator previously described except that the rotor is provided with a three-coil winding, rather than a single winding. The stator rotor is rotated by the computer by an amount determined by the correction to be applied.

Figure 6-197 shows the manner in which the differential generator is connected into the Selsyn system. The stator of the differential generator is connected to the stator of the Selsyn generator while the rotor is connected to the stator of the Selsyn control-transformer. As long as the rotor of the differential generator is in electrical alignment with its stator, as indicated in Figure 6-197, the voltages in the stator and rotor will be the same and the direction of magnetic flux the same. Thus, as indicated by the direction arrows, the position of the Selsyn generator rotor R_1, R_2, is transmitted directly to the control-transformer. This is the position of the differential generator when no correction is being introduced into the system by the computer and the turret guns are in alignment with the sighting station.

When the computer puts a correction into the Selsyn system the computer rotates the rotor of the differential Selsyn generator. In Figure 6-198 the rotor has been moved 30 degrees clockwise. This changes the voltages in the leads to the control-transformer stator so that the direction of magnetic flux in the stator is moved 30 degrees as indicated, producing an output voltage signal from the Selsyn control-transformer even though the Selsyn generator has not been moved. Hence, the correction put in by the computer pro-

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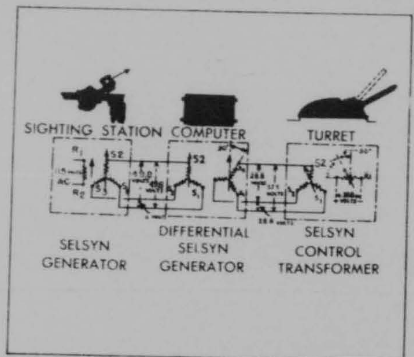

Figure 6—198. How Movement of Differential Selsyn Generator Rotor Affects Magnitude and Polarity of Voltage in Control-transformer Rotor.

duces a signal voltage to move the guns to the dotted line position.

In this way the voltages in the rotor windings of the differential generator vary in magnitude and polarity dependent upon the amount and direction in which the rotor is moved. Hence, the correction put in by the computer produces a signal voltage to move the guns to the dotted line position.

In this way the voltages in the rotor windings of the differential generator vary in magnitude and polarity dependent upon the amount and direction in which the rotor is moved. Since the three voltages in a Selsyn system represent a position, the differential Selsyn generator is a device for adding or subtracting a given angle to that position.

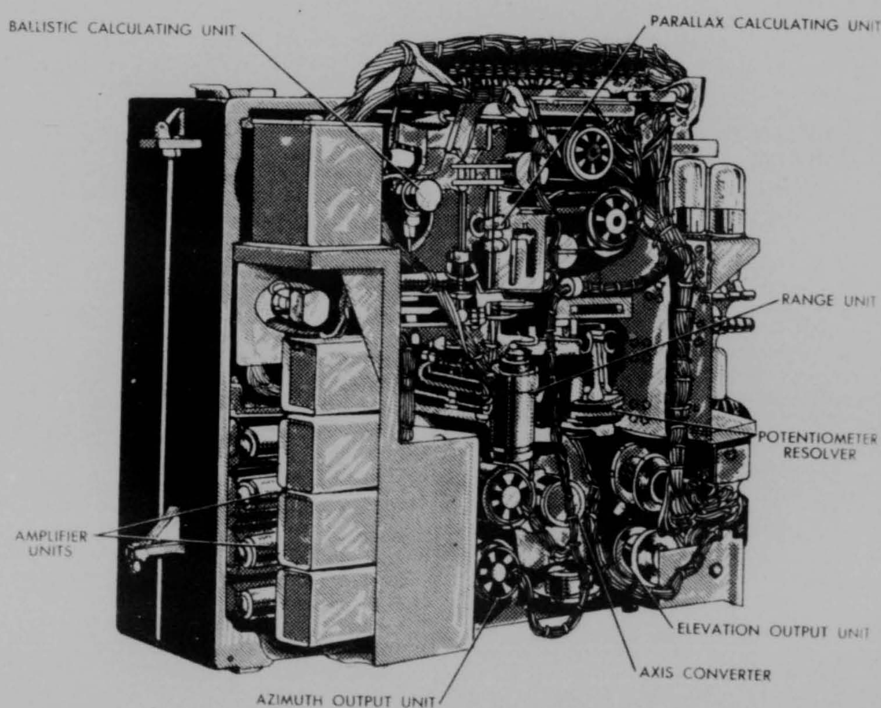

Figure 6—199. Single-parallax Computer, Model 2CH1C1 (Prototype).

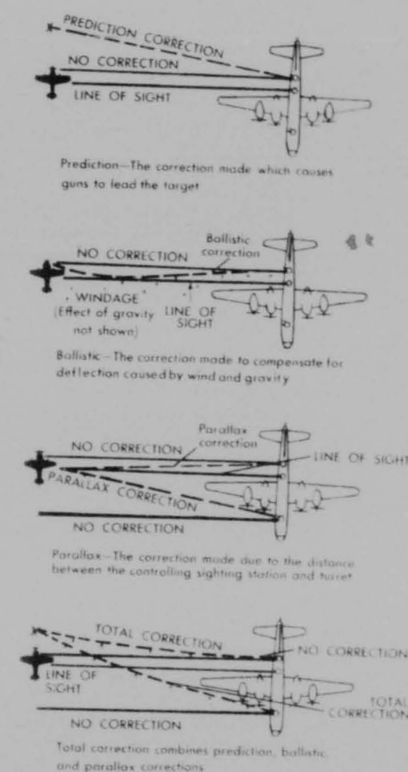

Figure 6—200. Lead, Ballistic, and Parallax Corrections.

5. COMPUTER, TYPE 2CH

General

Introduction. The type 2CH computer is designed (1) to allow a gunner to sight directly on his target, and (2) to cause the bore axes of the guns, on the turret or turrets which the gunner is controlling, to be changed from a position parallel to the line of sight to a position which will cause the projectile to hit the target.

One computer is used in conjunction with each of the five sighting stations. The five computers, however, are located remotely from the sighting stations and are connected only by electrical means. Single-parallax computers, Model 2CH1C1 (Figure 6-199) are used entirely.

Computer Corrections. (Figure 6-200). Each computer makes corrections for the following:

Ballistics. To compensate for windage and gravity forces which cause a projectile to deviate from a straight line after leaving the muzzle of the gun.

Parallax. To compensate for the distance along the longitudinal axis of the airplane between the turret and the sight which is controlling the turret.

Lead. To compensate for the distance the target travels from the time the projectile leaves the gun until it strikes the target.

How the Computer Corrections are Introduced into the System. The three corrections are added together and appear as a single total correction. This total correction is introduced into the system by means of differential Selsyn generators which are electrically connected between the Selsyn generator on the sighting station and the Selsyn control transformers on the turret. A single parallax computer has four differential Selsyn generators—1-31-speed azimuth, and 1-31 speed elevation. When the rotors of the differential Selsyn generators are rotated by the amount of the total correction—as determined by the computer—they will alter, or change, the signals from the Selsyn generators on the sighting station so that the guns on the turret will be changed (by the amount of the total correction) from a position parallel to the line of sight. This new gun position will cause the projectiles to strike the target.

Inputs Required by the Computer. In order to calculate the ballistic correction, the computer must obtain the following information:

Azimuth and elevation gun position.

True airspeed and density altitude (a function of altitude and temperature).

Range, or distance, of target from gunner's sight.

In order to calculate the parallax correction, the computer must obtain the following information:

Azimuth and elevation gun position.

Range, or distance, of target from gunner's sight.

In order to calculate the lead correction, the computer must obtain the following information:

Relative velocity of target with respect to the line of sight.

Range of target.

Density altitude (a function of temperature and barometric altitude).

Ballistics, as it affects the time of flight of the projectile.

Where the Computer Obtains its Necessary Inputs. Azimuth and elevation gun positions are obtained from the Selsyn system.

Range of the target is supplied by each gunner to his computer by means of the range potentiometer in his sight. This potentiometer is varied as the gunner adjusts his range handwheel, or grip, to keep the reticle spanning the target.

The true airspeed is obtained from the navigator's handset unit. This unit computes true airspeed from the indicated airspeed set in by the navigator. Density altitude is also obtained from the navigator's handset unit, being determined from the barometric altitude and temperature which are set in by the navigator.

Relative velocity of the target, with respect to the gunner's airplane, is furnished to the computer by two gyroscopes on the sighting station.

SECTION VIII—HARMONIZATION

1. INTRODUCTION

General

Harmonization is one of the most important and at the same time one of the most exacting of all the jobs which must be done to prepare the B-29 for a successful mission. Without proper harmonization, the best gunner in the world could never hit his target. Basically the job is the same as the harmonization of local power turrets. The line of sight and line of fire must be so adjusted that they are parallel to each other and stay that way when they move.

Problems of Harmonization

The RCT system makes harmonization a special problem. The B-29 has five turrets and five sighting stations all on different levels and at various distances from one another. The lines of sight from each turret and the RCT electrical system must be carefully adjusted so that the guns will always move accurately with the sights throughout their entire range of movement. Corrective mechanisms such as computers play no part in the harmonizing process and are disconnected during harmonization. (Computer switch in "out" position). Harmonizing, however, forms the basis for correct operation of the computer, since the corrections of the computer start off from parallelism of the line of sight and the gun bore axis. The first part of harmonization is the mechanical adjustments of the plane, sights, and turrets. The vertical axes of each turret and sight must be parallel to one another and perpendicular to the axes of the plane within the proper tolerance. The vertical axis of each turret and sight must be perpendicular to the longitudinal and transverse axes of the bomber within a tolerance of ½ degrees. The vertical axes of the turrets and sights must be parallel to one another within a tolerance of plus or minus ½ mil. Figure 6-201 and 6-201A show the proper axes relationships. The tolerance of ½ degrees between sights and turrets and axes of the ship is necessary for proper operation of the fire interrupter and contour followers.

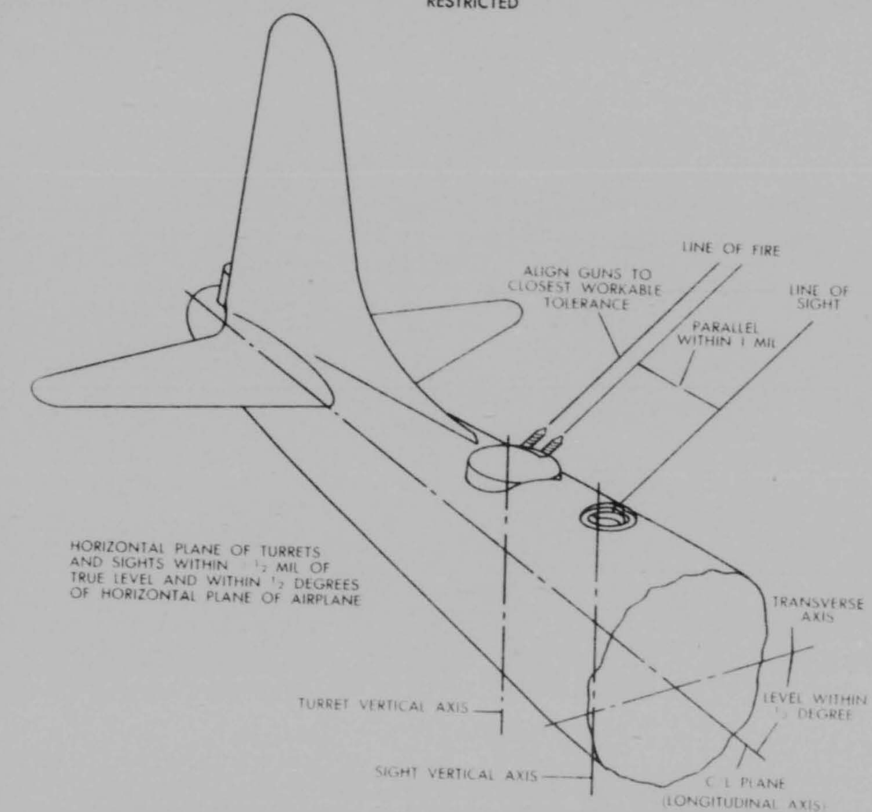

Figure 6—201. The Mechanical Tolerances.

2. LEVELING AIRCRAFT

It is necessary that the airplane be level in order to level the sights and turrets. This is done by six hydraulic jacks. Five of them are of twenty-ton capacity, and the tail jack of ten-ton capacity. Four jacks are placed under the wings at the proper jack pad positions. One is positioned at the nose, the pad being in the nose wheel well, and the tail jack is placed just ahead of the tail skid on its proper pad. When the B-29 sets at normal attitude it is approximately 2 degrees nose high. In leveling the ship the nose is lowered approximately fourteen inches. To do this it is necessary to partially retract the nose wheel. (Figure 6-202).

Placement of Jacks

Jacks are placed (on a base which will not move during the leveling) under wings and nose in preparation for lifting the ship. The nose wheel may be retracted during leveling if necessary or more convenient.

A longitudinal leveling bar and precision level is installed and the jacks adjusted until the level reads "zero." **Caution:** The level must

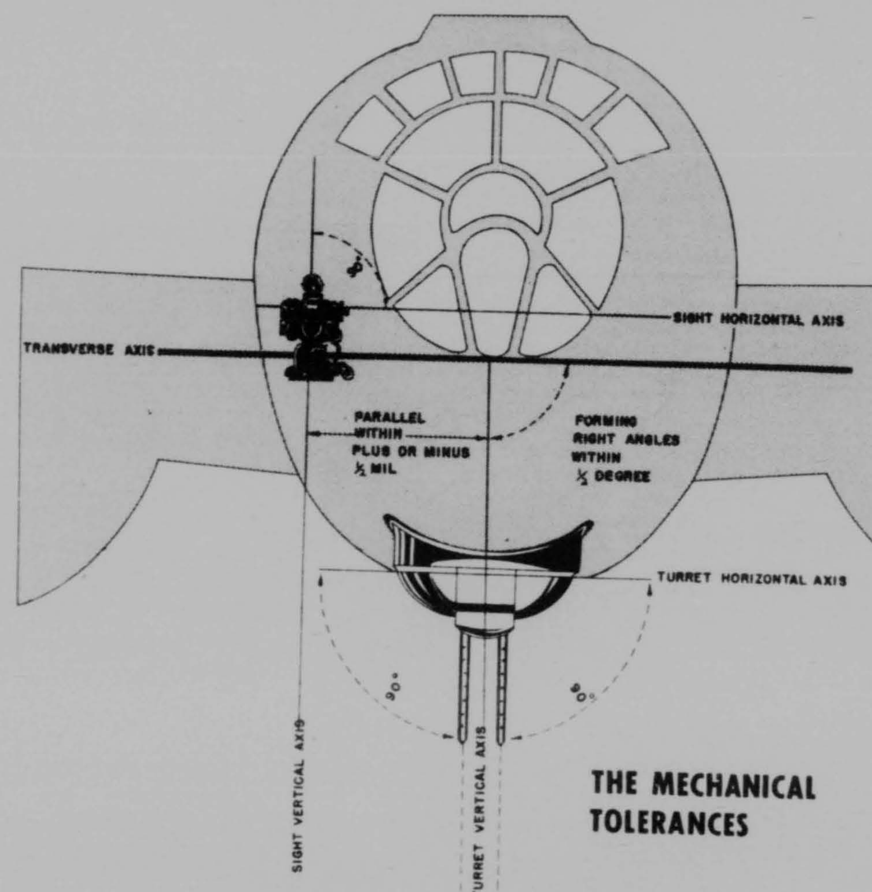

Figure 6—201A. The Mechanical Tolerances.

not be left unattended on the leveling bar. No attempt should be made to lift the airplane with the tail jack.

The transverse leveling bar and precision level are installed, and the jacks adjusted until the level reads "zero."

The longitudinal and transverse level are checked prior to, and at frequent intervals during, the leveling of turrets and sighting stations.

If it becomes necessary to level the ship with a transit, the same procedure should be followed, except that the checks for level are made with the transit. The longitudinal axis is checked for level by means of two points on the belly of the ship. The forward point is a rivet on the center line of the ship, an inch or two in front of the forward bomb-bay door opening. The aft point, which must be jacked to 6.39 inches higher than the forward point to level the airplane, is located a few inches

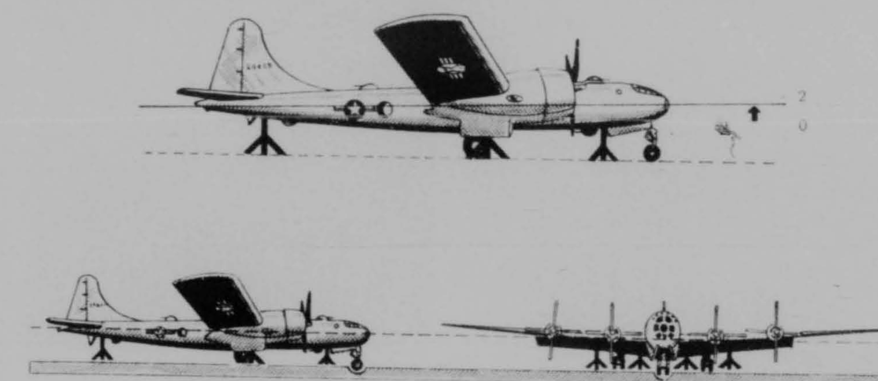

Figure 6—202. Leveling B-29.

aft of the rear bomb-bay door opening. This point can be definitely located by a small tapped hole which is on the center line of the airplane.

The transverse axis is leveled by setting the transit aft or forward of the ship with the telescope level and swinging the transit from a point underneath one inboard jack pad to a point under the inboard jack pad on the opposite side. It is necessary to measure down from the pad, on a line perpendicular to the level transit line of sight. The ship should be lifted as required to make the measurement between the transit line of sight and the jack pads exactly the same on both sides.

Gunner's Quadrant

The gunner's quadrant is used to check the level of sights and turrets. This instrument is calibrated down to fractions of mils and thus has a fine range of measurement. It is attached to the sights and turrets (as shown in Figures 6-203A, B, C, 204). To use the quadrant, the bubble is centered by the adjustable bar and adjustment knob; then a reading is taken on the calibrated arc and the Vernier adjustment knob.

Level (Align Vertical Axes of) Turret and Sighting Stations

When. The turret and sighting stations are leveled when:

Initial harmonizing is being accomplished; or

Turrets or sighting stations have been reinstalled or replaced; or

Maintenance checks indicate the desirability of releveling.

Where. The turrets and sights are leveled after the airplane is leveled as described. It has been recommended that the airplane be leveled outside the harmonizing yard when possible.

How. The planes of rotation (vertical axes) of the turrets and sighting stations must be

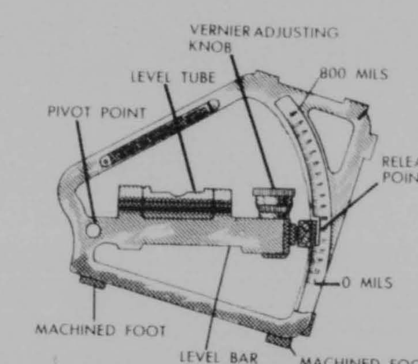

Figure 6—203. Gunner's Quadrant Levels.

Figure 6–203A. Gunner's Quadrant Levels.

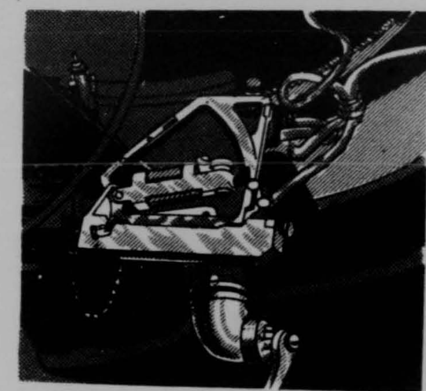

Figure 6–203C. Gunner's Quadrant Levels.

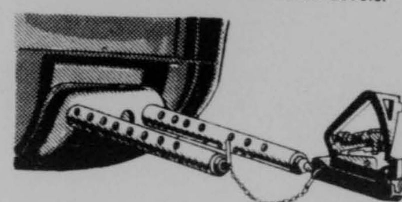

Figure 6–203B. Gunner's Quadrant Levels.

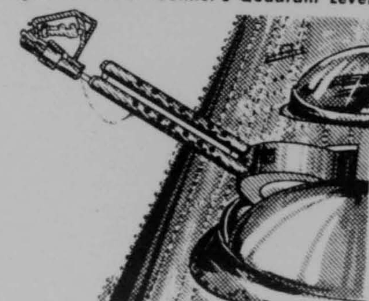

Figure 6–204. Gunner's Quadrant on Upper Turret.

parallel to each other within plus or minus 1/2 mil and must be within 1/2 degree of the level of the airplane. This is accomplished by aligning the vertical axis of the master turret (lower forward turret) with the transverse-longitudinal plane of the airplane and then aligning the vertical axes of all other sighting stations and turrets with that of the master. Also, the turrets must be installed so that the fore and aft index marks on the turret rings are parallel within 1/2 degree of the longitudinal center line of the airplane.

Longitudinal and transverse levels of the airplane should be checked.

Gunners quadrant and azimuth angle measuring sector are installed on the lower-forward turret, which is used as the master. (The angle measuring sector is used to locate points 15 degrees apart in azimuth.)

Guns are depressed to clear contour follower and lock in elevation.

The turret is rotated by 15-degree stops.

Level at each azimuth step is then read.

The tilt of turret is calculated.

Adjustment is made, as necessary, to meet tolerances specified above.

For all other turrets in turn, the level is checked, the tilt measured and adjusted as necessary to meet tolerances by shimming or the use of adjusting screws.

To the blister, tail, and upper-sighting stations, in turn, a level is attached, rotated and checked; the tilt is calculated, and shimmed as necessary to meet tolerances.

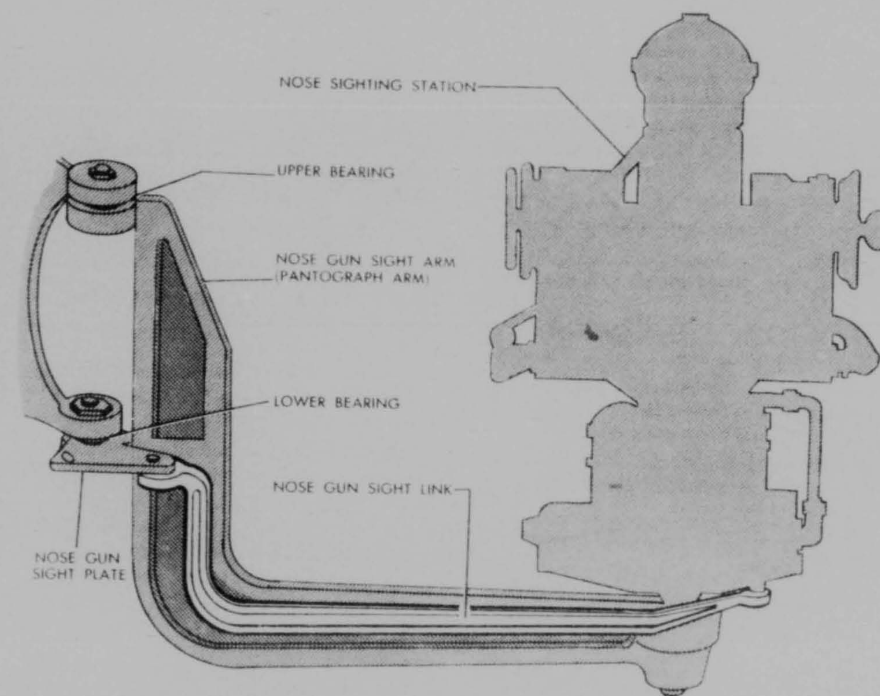

Figure 6–205. Rear View of Nose-sight Pantograph.

Since the nose-sighting station is mounted on a pantograph arm, it is not leveled by shimming under the base, as are the other sighting stations, but is leveled by adjusting the eccentric lower bushing of the main pantograph arm (Figure 6-205).

3. ALIGNMENT OF GUN AXES WITH TURRET AXES

The next step in harmonization is that of aligning the gun axes with the turret axes, i.e., making the guns in a turret parallel to each other and perpendicular to the trunnion axis (the axis around which the guns rotate when they are moved in elevation). This is done in the following manner.

When. The guns must be aligned when:

Initial harmonizing is being accomplished; or

Turret guns have been reinstalled or replaced; or

Maintenance checks indicate desirability of realigning.

Warning: Receivers of aligned guns must not be pulled unless necessary and then only one receiver is taken at a time. The cleaned receiver is then aligned with the one remaining in the turret. (It will then be unnecessary to go through the following gun alignment procedure.)

Where. The guns can be aligned with the airplane at normal or level altitude, in or out of the harmonizing yard. The airplane should be located on a level strip of ground where it will not settle.

How. The preferred method of aligning guns is described in detail below. However, the guns may be made parallel to each other but not aligned to turret axis by using only a distant target when conditions necessitate, although this method is less accurate.

If the airplane is exposed to the elements, it is suggested that it be steadied with jacks before proceeding.

The guns are swung up or down to clear contour follower and then locked in elevation.

The aligning level is placed in the right gun and the turret placed on aft azimuth index mark.

The level bubble is adjusted to level at this point and a reading made.

The inner ring is marked at the point 180 degrees from where the reading is taken (opposite "FWD" mark on outer ring).

The located point on turret inner ring is moved to the forward index mark and a reading made.

The difference of two readings is taken and divided in half.

After adding the least, or subtracting from the greater of the two readings, the resulting reading is set into the aligning level.

The turret is turned in azimuth until the bubble is level. This is the level axis.

This spot is marked on the outer ring using the regular inner ring index mark and a spot is marked on the outer ring 180 degrees away, using the spot on the inner ring located in preceding steps.

The guns are elevated or depressed in elevation until the elevation index marks match and lock. The guns should be about horizontal and broadside.

The level scales are set at 90 degrees and the rear trunnion mount of the right-hand gun adjusted in elevation until the level reads "zero."

With turret still set at level axes:

Level scales are set at zero.

Upper turret guns are elevated or lower turret guns are depressed until level reads "zero." They are then locked in elevation.

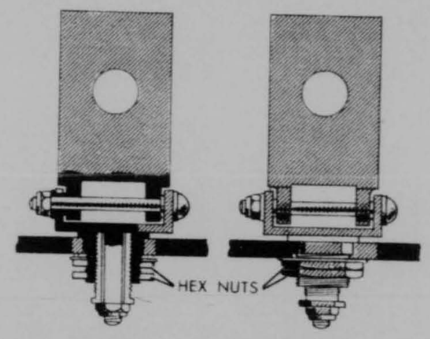

Figure 6–206. Azimuth Adjustment of Guns on Upper and Lower Turrets.

A reading of level axes is taken by rotating level 180 degrees in the bore of the gun. The level should read "zero."

Index lines are marked on saddle and saddle support trunnions to indicate this elevation position.

The level in the bore is rotated 90 degrees.

The rear trunnion mount of gun is adjusted in azimuth only until the level reads "zero."

The level is rotated 180 degrees in the bore and a check made to see that the level still reads "zero."

The right-hand gun is boresighted on a suitable parallax target (with crosshairs 7½ inches apart) or on a distant object and the left-hand gun adjusted in azimuth and elevation to make it parallel to right-hand gun.

The process is repeated for all but the tail turrets.

Cal. .50 tail guns are aligned on a suitable parallax target making adjustments at rear trunnion when necessary. An alternate method is described below.

The gun-alignment level is installed in cal. .50 gun and the turret moved in elevation until the reading is "zero." A level is inserted into the other cal. .50 gun and the gun adjusted in elevation (Figure 6-205) until the level reads "zero."

Sighting is made on a suitable boresight target and an adjustment made in azimuth (Figure 6-206) as required.

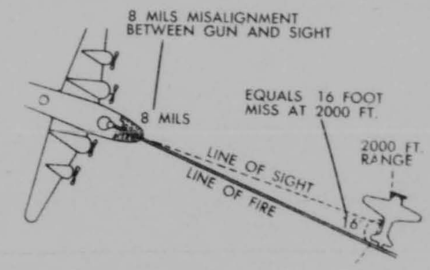

Figure 6–207. How Misalignment Affects Gun Fire.

Operational Check

When. An operational check is made:

When initial harmonizing is being accomplished.

For a maintenance check before harmonizing check.

Where. The operational check can be made at any convenient point where an energizer is available. However, if it is suspected that the system does not operate properly, the operational check should be made before the airplane is moved into the harmonizing yard. If the gunner's report indicates proper operation of the system, the plane can be moved into the harmonizing yard. The harmonizing yard is in great demand. Planes suspected of operational difficulties should be kept out of the yard.

Caution: The complete system must be given a visual check to make sure that parts of the system are all in place and properly connected, that all of the units are undamaged and that no personnel or equipment is in the way of moving parts.

Set Airplane in Harmonizing Yard

When. The airplane should be placed in the yard before proceeding with the electrical adjustments.

Where. The standard and approved method uses the middle-distant harmonizing yard. The long-range harmonizing yard is not to be used for initial harmonizing, but in emergencies may be used for replacement of individual sighting stations or turrets, or for after-flight harmonizing.

How. Procedure is as instructed in the paragraphs which follow.

Long-range Yard. The long-range yard is described briefly in this section. When locating the airplane in the harmonizing yard, each object should be distant enough or located in such a way as to reduce the parallax to the permissible tolerance when both the line of sight and the line of the gun bore are directed upon it. The sights and turrets must be aligned within a tolerance of 1 mil of each other.

For determining the distance at which a long-range target should be removed from the airplane to permit alignment within the tolerance, it should be remembered that a 1-mil error means a 1-foot error at a distance of 1,000 feet away for every foot of perpendicular or horizontal distance between the line of sight and the horizontal or vertical axes of turret (Figure 2-207). For example, a sighting station and turret combination with four-feet vertical parallax and six-feet horizontal parallax between the sighting station and the turret requires a target six thousand feet distant. (Parallax in feet [p] times 1,000 equals minimum distance of object [d], or: 1000p = d.)

Middle-distant Yard. The middle-distant yard's construction is described in this section. Targets are normally five-hundred feet from the plane but may be moved closer if necessary. Extreme care must be used in locating the airplane when closer targets are used. The possibility of error increases and closer tolerances must be held as targets are moved closer. (At seventy or eighty feet, a one-inch misalignment of the target causes approximately a one-mil error.)

The airplane is towed into the harmonizing yard.

A yard for the normal attitude of the airplane should be used if after-flight harmonizing, or harmonizing without the airplane level is planned.

The yard for the level attitude of the plane should be used if leveling (alignment) of sights and turrets is to be done in the harmonizing yard.

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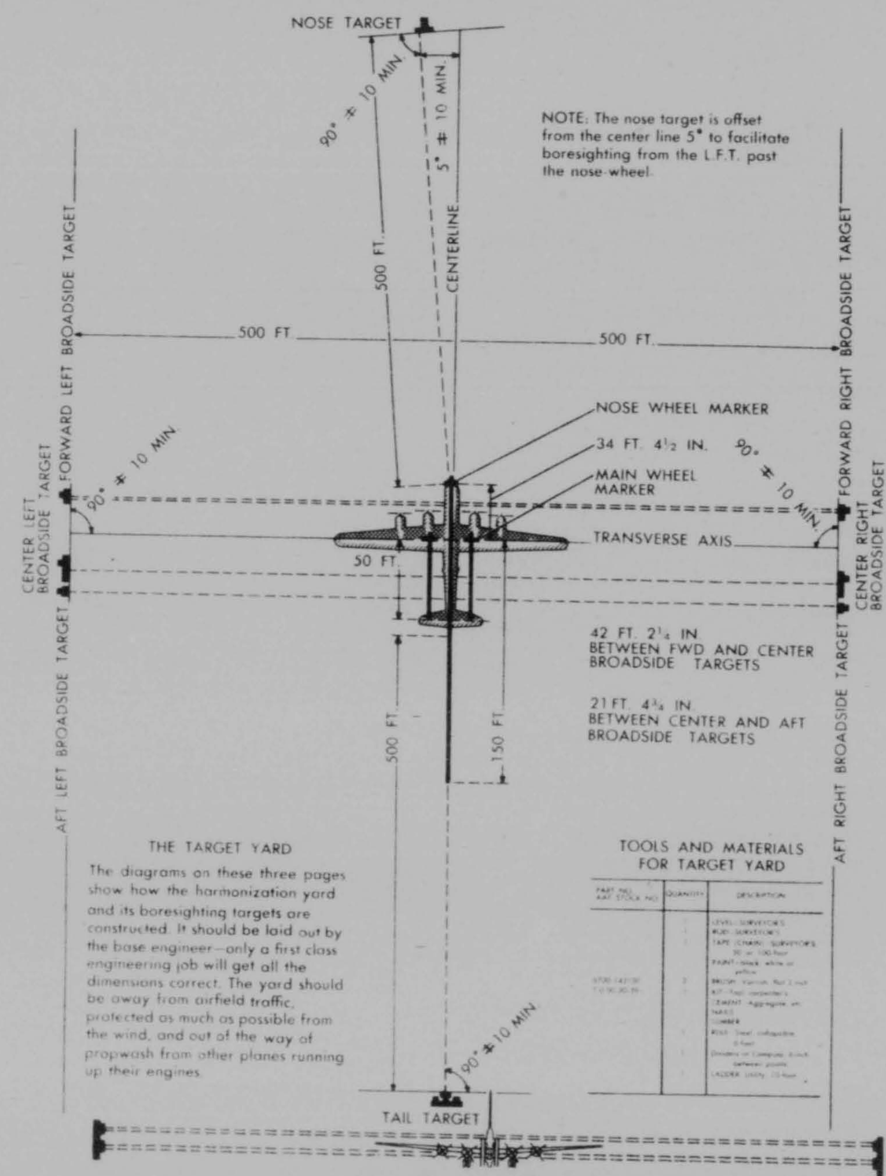

THE TARGET YARD

The diagrams on these three pages show how the harmonization yard and its boresighting targets are constructed. It should be laid out by the base engineer—only a first class engineering job will get all the dimensions correct. The yard should be away from airfield traffic, protected as much as possible from the wind, and out of the way of propwash from other planes running up their engines.

TOOLS AND MATERIALS FOR TARGET YARD

PART NO. AAF STOCK NO.	QUANTITY	DESCRIPTION
[illegible]	[illegible]	LEVEL—SURVEYOR'S
[illegible]	[illegible]	ROD—SURVEYOR'S
[illegible]	[illegible]	TAPE (CHAIN) SURVEYOR'S [illegible]
[illegible]	[illegible]	PAINT—black, white or yellow
[illegible]	[illegible]	BRUSH—[illegible]
[illegible]	[illegible]	KIT—Tool, carpenter's
[illegible]	[illegible]	CEMENT—[illegible]
[illegible]	[illegible]	LUMBER
[illegible]	[illegible]	ROD—Steel [illegible]
[illegible]	[illegible]	Dividers or Compass [illegible]
[illegible]	[illegible]	LADDER [illegible]

Figure 6—208. The Target Yard.

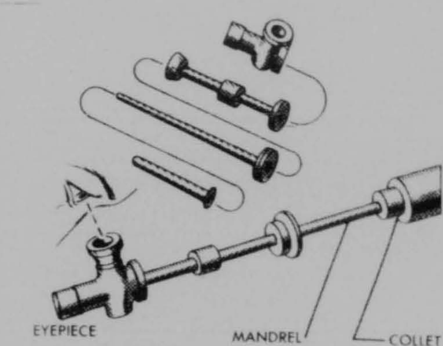

Figure 6—209. Boresight Tool.

Caution: The attitude (level or normal) of the airplane must always be correct with respect to the attitude (level or normal) of the harmonizing-yard targets.

Wheels should be located on their proper marks. The airplane should be towed into the yard with the nose wheel following the painted center line of the airplane. The wheels of the airplane should be placed within one inch of their proper location in a seventy- or eighty-foot yard, and within six inches in a five-hundred-foot yard.

Jacks are placed under the nose, wing, and tail pads.

The airplane is adjusted, with jacks if necessary, to place the longitudinal center line of the plane in the same plane as the longitudinal center line of the harmonizing targets. If the airplane is lifted very high with jacks, it is possible for wind to blow the airplane off; this may be avoided by placing the harmonizing yard in a sheltered location.

The transverse axes of the airplane are adjusted to a level position (Figure 6-208).

Note: The nose target is offset from the center line 5 degrees to facilitate bore-sighting from the L.F.T. past the nosewheel.

For a quick check to determine if the airplane's center line agrees with target's center line the blister sight is swung, stowed in elevation, from alignment on their respective targets to the blister sight marks on the forward broadside targets. The airplane is jacked slightly to obtain proper alignment. Both sights should be checked.

4. BORESIGHTING

In order to properly boresight the guns on their respective targets the J-2 boresight tool is used (Figure 6-209).

The boresight tool used in B-29 harmonization is the standard muzzle-type tool in the J-2 Boresight Kit. To use it, the collet, or sleeve, is first placed inside the gun barrel from the muzzle end. Then the mandrel, or spindle, is placed into the collet. Now, by sighting through the eyepiece, using any convenient arrangement of lenses, the observer will see exactly what would be seen if he were sighting through the barrel. The boresight tool, however, reverses the image. If the eyepiece is on either side of the gun, normal right and left will be reversed in the image. If the eyepiece is on top, the image will be upside down. The eye should be kept as close as possible to the center of the eyepiece; holding the eye off to one side or the other will introduce an error. Before using the tool, the mandrel must be checked to see that it is not bent. To check it, the tool is placed in the muzzle, on some small distant object, is boresighted. Then the tool is carefully rotated, stopping and checking at various points to make sure that the object is still exactly centered in the eyepiece.

5. THE MASTER SIGHTING STATION

All steps which have been performed up to this time have been building up to the most critical part of harmonization. These are the actual electrical adjustments necessary to establish perfect parallelism between the line of sight and the line of fire of all sight and turret combinations. It is important that these adjustments be made in the proper sequence. As a starting point the right blister sight is used, and which, for that reason is referred to as the master sighting station. Two crews may harmonize a ship at one time: one crew can work forward from the right blister sight making the necessary electrical adjustments; meanwhile the second crew

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works aft from the right blister sight making similar adjustments. Assuming that one crew is performing the work, the explanation will start with the combination which is harmonized first by the forward crew.

6. TYPICAL PARALLELING PROCEDURE

Following is the procedure for paralleling the lower forward turret to the right blister sight. (This procedure is essentially the same for other sighting stations and turrets.)

The entire system is given an operation check to detect any possible malfunctions.

All servos are balanced by the following method:

All sight Selsyn caps are removed.

Amplidyne contactor points are blocked open.

AC turret power and selector switches are turned on and the block action switch closed.

The servo is balanced by adjusting the potentiometer to obtain zero voltage across M&N and P&R.

All switches are turned off, the action switch is unblocked and the amplidyne contactor is unblocked.

Selsyns are zeroed on the master sighting station.

AC power switch is turned on.

Right blister sighting station is locked forward and horizontal.

Selsyns are accurately zeroed with the Roller-Smith Analyzer to within the proper tolerance (1/4) volt.

All sight Selsyn caps are replaced.

Warning: To prevent personal injury the 1-speed CT (or generator) Selsyn caps must be removed immediately after the guns have been brought into approximate alignment with the sighting station. After the 31-speed Selsyns have been adjusted, turret power SW is turned off before replacing 1-speed Selsyn caps. Selsyns should never be rotated rapidly in either direction.

The selector switches and disconnect switch are set for control of the lower forward turret from the right-blister sighting station.

The AC turret power switches on nose control box are closed and the action switch closed and blocked to align lower-forward turret with the right-blister sighting station.

Parallax-eliminating disk is inserted, in right-blister sight, on the dust-cover glass.

The right-blister sight station is aligned and locked on its broadside target using azimuth and elevation sight locking tools.

Turret power switch is turned off.

One-speed CT Selsyn caps (azimuth and elevation) are removed.

The turret power switch is turned.

The boresight tool is placed in the right-hand gun of the lower forward turret.

Note: In looking through the boresight tool, care should be taken to see that guns are brought on their correct target.

Crosshairs are positioned on the proper target by rotating the 31-speed CT Selsyns very slowly in the proper direction (both azimuth and elevation).

With turret on the target, the turret-power switch is turned off, the 1-speed CT Selsyns caps are replaced, and the 1-speed CT Selsyns (azimuth and elevation) are adjusted to zero (0) error signal to within 1/4 volt by measuring across the grounds of both 1-speed signal transformers at the servo.

The boresight tool is removed.

The turret is moved off reference in azimuth and elevation and the turret power switch is closed.

The boresight tool is installed in the RH gun and check work is performed.

The action switch is released and all switches are opened.

SECTION IX—GLOSSARY OF TERMS

Advanced (Future) Line of Sight. The line from the sight to the target at the instant of impact.

Advanced (Future) Position. The position of the target relative to the gunner's airplane at the instant of impact.

Advanced (Future) Range. The range at the instant of impact of the projectile with the target.

Air Density. The density of the air relative to standard density.

Altitude Correction. The correction which must be made in the altimeter reading to compensate for a nonstandard temperature.

Amplidyne Generator. A combination DC motor DC generator—which amplifies the less than one-watt input to its control field into more than 500 watts output.

A N Connector. A connector to provide means for quickly connecting and disconnecting a unit.

Azimuth. The angle, measured in the azimuth plane, between the nose of the ship and the elevation plane through the target or point of reference.

Azimuth Plane. The plane of the fore-and-aft axis of the airplane and the wings.

Break-down Voltage. The voltage at which ionization and conduction take place in a gas or vapor.

Collector Ring. A unit used to provide a means of introducing power to the turret and ring sight, permitting full rotation without twisting the incoming cables.

Contour Follower. A mechanism used to provide a means for raising the guns so they cannot point at the sighting station.

Dynamotor. A combination DC motor AC generator—taking in DC from the airplane generator and furnishing AC to the fire-control system.

Elevation. The angle, measured in the elevation plane, between the azimuth plane and the target or point of reference. It is 90 degrees minus the zenith distance.

Elevation Plane. Any plane through the zenith.

Fire Interrupter. A mechanism which prevents the turret guns from firing on portions of the airplane (including propellers).

Harmonization. The process of paralleling the line of sight and the gun bore axis through all points covered by them simultaneously.

Indicated Air Speed. The reading of the air-speed indicator.

Inertia Wheel. A wheel used in sights to smooth the motion of the sight in elevation through its flywheel action.

Initial Velocity. The velocity, relative to the gun, with which the projectile leaves the muzzle.

Initial Yaw. The yaw at the instant the projectile leaves the muzzle of the gun.

Ionization. Process by which ions are produced in solids, liquids, or gases.

Jump. The apparent initial change of direction of the trajectory.

Lead Angle. The angle between the present and the advanced lines of sight.

Line of Sight. The line from the sight to the target determined by the reticle or cross hairs.

Neon Lamp. Consists of two electrodes sealed within a neon gas-filled glass bulb.

Pantograph. An extending arm.

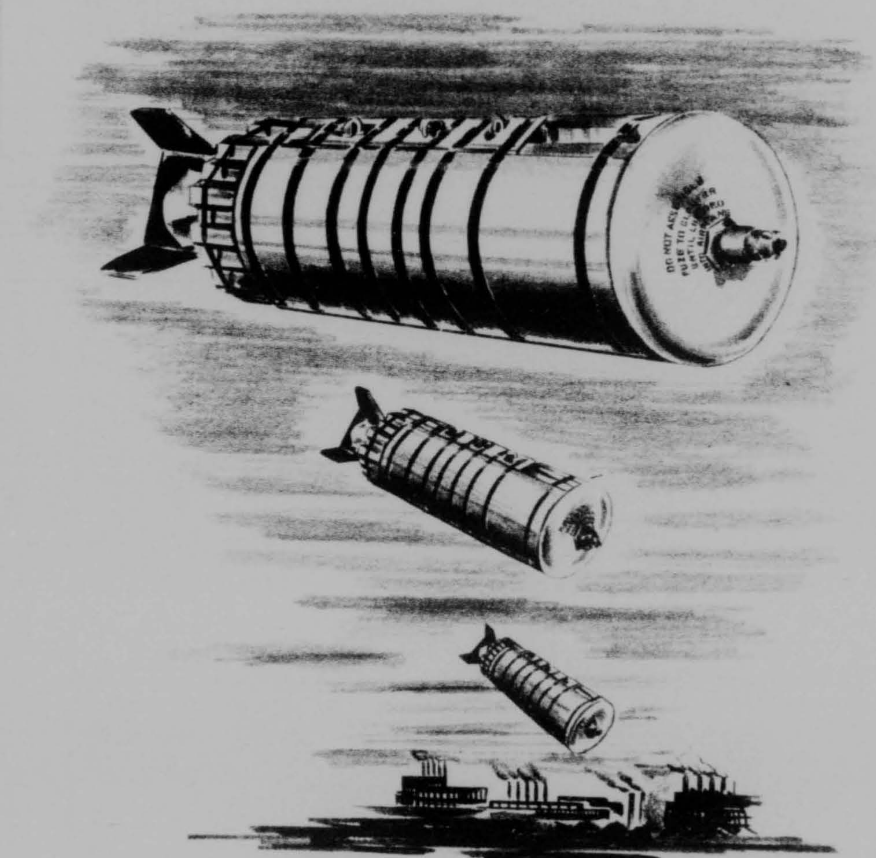
Parallax. The correction necessary to compensate for the fact that the gun and the sight are not at the same point.

Parallax Base Length. The distance between the gun and the sight.

Potentiometer. A variable voltage divider; a resistor which has a variable contact arm so that any portion of the potential applied between its ends may be selected.

Present Range. The range at the instant of firing.

CHAPTER 7— CHEMICAL WARFARE



SECTION 1 — CHEMICAL AGENTS

1. INTRODUCTION

Chemical Warfare is defined as the use of chemical substances to produce personnel casualties by inhalation of, or physical contact with, poisonous materials, to deny observation by use of screening smokes or to destroy combustible material by means of incendiary munitions. The scope of chemical warfare is very broad, however, and includes weapons, munitions and protective materiel. Weapons and munitions pertaining to this subject have been discussed in chapters 6 and 7 of Volume I. This chapter is devoted to a study of chemical agents, tactics and protective materiel.

CHEMICAL WARFARE AGENTS									
CLASS		AGENT	SYMBOL AND MARKING	ODOR	COLOR AND STATE IN FIELD	PERSISTENCY	EFFECTS ON BODY	PROTECTION	FIRST AID
CASUALTY AGENTS	BLISTER GASES	MUSTARD	H GREEN GREEN	Garlic Horse-Radish	Dark Oily Liquid Or Colorless Gas	3 To 20 Days Depending On Temperature	Irritates Eyes And Lungs. Blisters Skin.	Gas Mask, Protective Cover, And Clothing	Pinch-Blot Liquid From Skin. Rub Ointment In With Fingers. Remove: Repeat. Rub Bal In Eyes For Liquid H. Wash With Water.
		NITROGEN MUSTARDS	HN GREEN GREEN	Soapy, Fishy, To Very Little Odor	Oily Liquids Soft Solids Or Colorless Gases	1 Day To Several Weeks	Irritates Eyes And Lungs. Blisters Skin. Affects Blood And Nerves.		Wash Skin With Soap And Water. Rinse Eyes With Water 30 Sec To 2 Min.
		LEWISITE	L GREEN GREEN	Geraniums	Dark Oily Liquid Or Colorless Gas	1 To 7 Days	Irritates Eyes And Lungs. Blisters Skin. Causes Tears.		Treat Same As Mustard.
	CHOKING GAS	PHOSGENE	CG GREEN	Fresh Hay Corn Ensilage	Colorless Gas	1 To 10 Min.	Attacks Lungs. Choking And Coughing.	Gas Mask	Keep Warm. Loosen Clothing. Give Warm Non-Alcoholic Liquid To Drink.
	BLOOD AND NERVE POISONS	HYDROCYANIC ACID	AC GREEN	Almonds	Colorless Gas	1 To 10 Min.	Dizziness, Headache, Convulsion, Paralysis.		Artificial Respiration. Amyl Nitrite Capsule.
		CYANOGEN CHLORIDE	CK GREEN	Odorless	Colorless Gas	1 To 10 Min.	Dizziness, Headache, Convulsion, Paralysis.		Artificial Respiration. Amyl Nitrite Capsule.
		TABUN OR GREEN RING THREE	GA GB GD	Fruity Odor	Colorless Liquid	10 Min To 12 Hours	Pupil Of Eye Contacts, Headache, Tightness In Chest, Nausea, Diarrhea, Death.	Gas Mask Protective Clothing	Put On Mask. Wash Liquid Off Skin. Give Artificial Respiration.
HARASSING AGENTS	TEAR GASES	CHLORACETOPHENONE	CN RED	Apple Blossoms	Colorless Gas	10 Min.	Eye And Skin Irritation. Crying.	Gas Mask	Do Not Rub Or Bandage Eyes. Face Wind
		CHLORACETOPHENONE SOLUTION	CNS CNB RED	Sweetish	Liquid Or Colorless Gas	1 To 50 Min.	Eye And Skin Irritation. Crying.		Do Not Rub Or Bandage Eyes. Face Wind
	VOMITING GAS	ADAMSITE	DM RED	Coal Smoke Very Little Odor	Yellow Smoke	10 Min.	Headache, Nausea, Violent Sneezing, Temporary Mental Depression.		Remove To Fresh Air Keep Moving. Gargle Water. Wash Nasal Passage.
SMOKES	SCREENING SMOKES	WHITE PHOSPHORUS	WP SMOKE YELLOW	Burning Matches	White Smoke		Solid Particles Burn Holes In Skin.	Avoid Particles	Place Wet Rag Or Mud On Burning Area Of Skin.
		HC MIXTURE	HC SMOKE YELLOW	Sharp Acrid	Gray Smoke		Very Irritating In Long Exposure	Wear Gas Mask When Exposed For Long Periods	None.
		SULPHURTRIOXIDE CHLORSULPHONIC ACID	FS SMOKE YELLOW	Acrid	Dense White Smoke		Irritates Skin. Liquid Produces Acid Burn.	Wear Gas Mask When Exposed For Long Time	Wash With Water Immediately.
INCENDIARIES	SCATTER TYPES	JELLIED GAS (NAPALM)	NP PURPLE	Burning			Burns.		Smother Burning Area. Treat As Ordinary Burn.
		MIXTURE OF OILS, LIQUID ASPHALT, RESINS, MAGNESIUM DUST, AND OXIDES.	PT 1 PURPLE	Burning			Burns.		Smother Burning Area. Treat As Ordinary Burn.
	INTENSE TYPE	MAGNESIUM	MG PURPLE		White Smoke White Flame	8 To 10 Min.	Burns.		Smother Burning Area

Figure 7–1. Chemical Warfare Agents.

PRIMARY TACTICAL CLASS		NAME	CWS SYMBOL	HOW TO DETECT: ODOR (Usually Described As)	HOW TO DETECT: COLOR AND STATE IN FIELD	HOW TO DETECT: DETECTION DEVICES	Persistency Depending On Weather Terrain And Methods Of Dispersion	EFFECT ON BODY	PROTECTION	FIRST AID: INDIVIDUAL SOLDIER	FIRST AID: GAS CASUALTY FIRST AID KIT	POSSIBLE METHOD OF DISPERSION
CASUALTY GASES	BLISTER	MUSTARD GAS	H	Garlic, Horseradish	Dark, Oily Liquid Evaporates Slowly	Vesicant Detector Paint, Paper, M9 And M4 Detector Kits, And M7 Crayon. (Crayon Not Satisfactory For HN)	1 To 20 Days	Injures Eyes And Lungs Blisters Skin	Gas Mask, Protective Clothing, Eyeshields Against Spray Use Individual Protective Cover.	Flush Eyes With Water From Canteen. Blot Liquid From Skin. Use Protective Ointment According To Directions.	Use Item No. 9, Protective Ointment. If Reddening Has Appeared Use Item No. 2, Calamine Lotion	Land Mine Spray And Bomb Artillery Rocket Gun Mortar Bulk Contaminating Vehicle
		NITROGEN MUSTARDS	HN	If Any Very Slight, Fishy Or Soapy	Liquid Or Soft Solid Evaporates Slowly		1 Hr To Several Weeks					
		LEWISITE	L	Irritating May Resemble Geraniums	Oily Liquid Evaporates Slowly	Vesicant Detector Paint, Paper And Crayon	1 To 7 Days			Use Bal Ointment In Eyes Blot Liquid From Skin Use Protective Ointment According to Directions.	Bal Ointment Or No. 5 Eye Solution M-1, (BAL)	
		PHENYLDICHLORARSINE	PD	Irritating	Liquid Evaporates Slowly	Vesicant Detector Paint, Paper And Crayon, M9 Detector Kit (ED And MD Only)	1 To 40 Days					
		ETHYLDICHLORARSINE	ED									
		METHYLDICHLORARSINE	MD				1 To 12 Hours					
	CHOKING	PHOSGENE	CG	New Mown Hay Cut Corn Ensilage	Colorless Gas	M9 Detector Kit	1 To 10 Minutes	Causes Choking And Coughing. Injures Lungs	Gas Mask	Keep Quiet And Warm		Bomb Artillery Mortar Cylinders Rocket Gun
		CHLORPICRIN	PS	Like Flypaper	Colorless Liquid Slowly Evaporates	None	1 Hour To One Week	Causes Tears, Coughing And Vomiting		Face Into Wind Do Not Rub Eyes Keep Quiet And Warm		
	BLOOD AND NERVE	CYANOGEN CHLORIDE	CC	Irritating	Colorless Gas	M9 Detector Kit	1 To 10 Minutes	Paralyzant Injures Lungs Causes Tears	Gas Mask	Artificial Respiration	Use No. 7 Amylnitrite According To Directions.	Bomb Artillery Mortar Rocket Gun Frangible Grenade
		HYDROCYANIC ACID	AC	Bitter Almonds	Colorless Gas	None		Paralyzes Respiratory System. Dizziness, Coma				
		ARSINE	SA	Slight, May Be Like Garlic				Poisons Blood And Nerves		Keep Quiet		
HARASSING GASES	VOMITING	ADAMSITE	DM	Very Little Odor	Yellow Smoke	None	1 To 10 Minutes	Causes Vomiting Sneezing Headache And Mental Depression	Gas Mask	If Unable To Carry On, Loosen Clothing, Wash Skin With Soap And Water, Rinse Nose And Throat With Water	Use Item No. 1 Chloroform	Bomb Artillery Mortar Grenade Candle
		DIPHENYLCHLORARSINE	DA		White Smoke							
		DIPHENYLCYANARSINE	DC	Mixture Of Garlic And Bitter Almonds								
	TEAR	CHLORACETOPHENONE	CN	Apple Blossoms	Colorless Gas	None	1 To 10 Minutes	Causes Tears And Irritates Skin	Gas Mask	Do Not Rub Eyes Face Into Wind		Artillery Grenade Candle
		BROMBENZYLCYANIDE	BBC	Sour Fruit	Liquid Evaporates To Form Gas		Several Days					
		TEAR GAS SOLUTION	CNS	Sweetish			1 To 5 Hours		Gas Mask, Individual Protective Cover Against Spray	Face Into Wind Do Not Rub Eyes Wash Skin Touched By Liquid With Water.		Bomb Spray Artillery Mortar
SCREENING SMOKES		WHITE PHOSPHORUS	WP	Choking, Mildly Irritating	White Smoke And Burning Particles	None		Solid Particles Burn Skin	Avoid Burning Particles	Put Wet Rag On Affected Skin Keep Wet Until Particles Are Removed By Picking Out With Forceps	Use No. 3 Copper Sulphate Solution According To Directions	Bomb Artillery Mortar Grenade
		SULFUR TRIOXIDE CHLORSULFONIC ACID	FS	Acrid	Dense White Smoke			Smoke Not Dangerous In Normal Field Concentrations, Liquid Droplets Burn Skin	Gas Mask In High Concentrations Or In Enemy Smoke	Wipe Off Liquid. Wash With Water		Bomb And Spray Artillery Mortar Frangible Grenade
		TITANIUM TETRACHLORIDE	FM									
		HC MIXTURE	HC	Sharp, Acrid	Gray Smoke			Not Dangerous In Normal Field Concentrations		None		Artillery Grenade Pot
INCENDIARIES		MAGNESIUM	TH		White Smoke White Flame	None		Causes Burns	No Protection Available	Flood Affected Parts With Water, Remove Particles Treat As A Burn		Bomb And Bomb Cluster Grenade
		THERMIT	TH		Orange Colored Glow							
		GELLED GASOLINE OR OIL	IM NP		Black Smoke Reddish Flame					Treat As Burn		Bomb Artillery Rocket Gun Flame Thrower Frangible Grenade
READY REFERENCE CHART TO CHEMICAL WARFARE AGENTS												

Figure 7–2. Reference Chart to Chemical Warfare Agents.

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COMMON NAME	WHITE PHOSPHORUS	FS MIXTURE	HC MIXTURE	FM	FOG OIL
Chemical Name	White or Yellow Phosphorus	Sulfur Trioxide+ Chlorsulfonic Acid	Hexachlorethane Mixture	Titanium Tetra-chloride	None
CW Symbol	WP	FS	HC	FM	*SGF1 or SGF2
Smoke in Air	Phosphoric Acid in H_2O	HC1 and H_2SO_4 in H_2O	Zinc Chloride in H_2O	Mainly Titanium Hydroxide with some HC1 and H_2O	Oil and water
Munitions suit-able for use	Explosive-type Munitions	Explosive-type Munitions or spraying devices	Burning-type Munitions	Explosive-type Munitions or spraying devices	Mechanical smoke generator
TOP Value (sq. ft.)	3500	2240	2000	*1900	Undeter-mined

* SGF1 - (Smoke Generator Fog - Warm Weather Oils)
SGF2 - (Smoke Generator Fog - Cold Weather Oils)

Figure 7–3. Principal Screening Agents.

2. CHEMICAL AGENTS

Chemical substances used for chemical warfare are called chemical agents. There are three categories of chemical agents: war gases, screening smokes and incendiaries. Only some forty chemical compounds possess the properties necessary for use as military agents. This may seem odd in view of the fact that there are over 800,000 compounds known to science today but thirty-five years of research has shown otherwise. While there are certain different requirements which war gases, screening smokes and incendiaries must meet, all must possess the following characteristics: ease of manufacture; availability of cheap, raw materials in the continental United States; stability in the presence of moisture, and in storage; non-corrosive to steel containers; and ability of withstanding an explosion when detonated. All agents presently standardized by the National Military Establishment are discussed in succeeding paragraphs. There are other agents, not discussed herein, which are under development by major world powers. From time to time it is logical that other new agents will be discovered and standardized. The Department of the Army Chemical Corps is charged with all research, development, standardization, procurement, storage, issue and maintenance of chemical warfare materiel. As such, the Chemical Corps delivers the products of the Department of the Air Force, Department of the Navy and the remainder of the Department of the Army for operational use. Each chemical agent has a symbol, assigned by the Chemical Corps, which for practical purposes identifies the agent. These symbols are very convenient since most agents have long complex names. Elsewhere in this chapter, agent symbols will be used exclusively.

3. WAR GASES

War gases are chemical agents which are used to produce personnel casualties and/or harassing effects. For convenience and to insure systematic treatment they are classified according to tactical use, physiological effect and persistency as indicated in Figure 7-1. From a tactical standpoint there are casualty, harassing, choking, tear and vomiting gases; and from a persistency standpoint there are nonpersistent and persistent gases.

Casualty Gases

Casualty gases are those capable of producing serious injury or death in field concentrations.

MUSTARD BURN 24 HOURS AFTER EXPOSURE

MUSTARD BURN TWO WEEKS AFTER EXPOSURE

Harassing Gases

Harassing gases are those which force the enemy to wear masks with a resultant and slowing or hampering of operations. Only those which produce this result with a small quantity of munition are considered primarily as harassing gases.

Blood and Nerve Poisons

These are gases which are absorbed into the body, producing their effect by interference with respiration and other body functions. Body absorption may be either through the lungs or by means of a liquid agent on exposed skin. Protection is afforded by gas masks and protective clothing.

Blister Gases

Blister gases are used for casualty effect (or threat of casualties) so that the use of ground may be restricted and operations hampered. They injure eyes and lungs and blister the skin, penetrating deeply into all exposed flesh. Protection is afforded by gas masks and protective clothing which covers the entire body.

Choking Gases

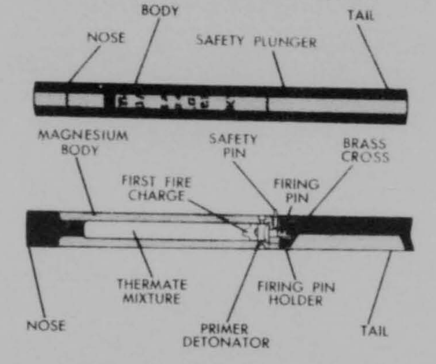
The effect of choking gases is to injure unprotected personnel in the nose, throat, and lungs. Membranes swell, lungs fill with liquid; death results from lack of oxygen. Thus these gases "choke" an individual. Protection requires only a gas mask.

Tear Gases

Tear gases are used for harassing purposes, producing copious tears and irritating the skin. Personnel casualties do not result from their use, therefore tear gases are used for training purposes and riot or mob control. Gas masks provide adequate protection.

Vomiting Gases

These are used for harassing purposes in riot or mob control work. Vomiting gases act in accordance with their name and cause great discomfort temporarily. Gas masks provide protection. One feature of interest is the fact that these agents are normally solids which vaporize, when heated, to form smokes.



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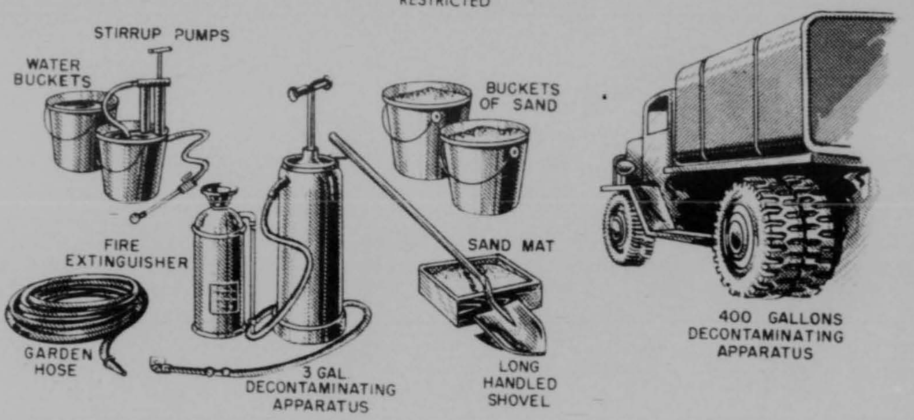


PROTECTIVE EQUIPMENT FOR DEFENSE AGAINST INCENDIARIES

Nonpersistent Gases

"Persistency" means the length of time a war gas normally remains effective in the open at point of dispersion. "Effective" means that the gas is capable of producing casualty or other intended effect on unprotected personnel. Nonpersistent gases are those which are normally effective in the open for ten minutes or less at the point of dispersion.

Persistent Gases

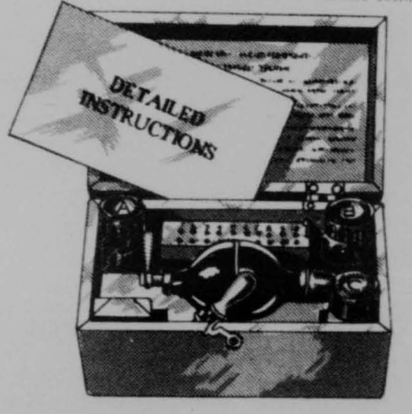
Persistent gases are those which normally are effective in the open at the point of dispersion for more than ten minutes. A further division is sometimes made into moderately persistent (ten minutes to twelve hours) and highly persistent (more than twelve hours).

Description of Gases

Brief descriptions of the more generally discussed war gases are tabulated in Figure 7-2. These data are limited to characteristics important in field identification and concern war gases available to the National Military Establishment. They are not necessarily identical with all possible enemy war gases and some are not standard United States agents.

4. SCREENING SMOKES

Screening smokes are chemical agents which, when burned, hydrolyzed, or atomized, produce a dense, white, obscuring smoke. Smoke is used to deny observation to the enemy, to reduce the effectiveness of his fire and to confuse or deceive him. Both white and colored smokes are used for signaling. These agents are not further classified since all are used as smokes and all are nonpersistent. Their physiological properties, while injurious, do not warrant detailed classification since these injurious effects are not shown by the smoke but by the agent from which the smoke is produced. A screening smoke which possessed highly toxic properties would be unsuitable since it is often used in friendly areas. The general characteristics of all satisfactory screening smokes are shown in Figure 7-3. Heavy concentrations of smoke tend



CONTENTS OF H VAPOR DETECTOR KIT M4

to nauseate personnel slightly after a prolonged exposure. For this reason and because smoke may be used to camouflage war gases, it is customary to wear gas masks in smoke clouds.

5. INCENDIARIES

Incendiaries are chemical agents which are used primarily to ignite combustible material and so destroy by fire. As such they are one of the most devastating strategic weapons available today. Protection against incendiaries is not a problem in the sense that protection against war gases and screening smokes are, rather it is a problem in defense against air attack. Therefore it will be treated as a special topic in later paragraphs.

6. DETECTION AND IDENTIFICATION

War gases may be detected without aid of special equipment by one or more of the following means; method of release, sensation, odor and appearance. Generally speaking, chemical-filled munitions have a much lower order of detonation than the same type munitions filled with HE. War gases, either in liquid or vapor form, may give a burning, biting, choking or prickly feeling in the nose, throat, lungs, or on the skin. Not all gases have characteristic odors, and the odors of the war gases that do have odors may be obscured by other smells. However, personnel whose duties call for specialized training should learn how a specific chemical agent smells to them. As an aid to positive identification of specific agents, for intelligence or other purposes, detection devices of various types have been developed and are issued to troops. These devices are discussed in later paragraphs.

SECTION II—TACTICS AND TECHNIQUES

1. DEFINITIONS

There are many unfamiliar terms applicable to the field of chemical warfare. Some of these terms have been defined previously and others will be defined in subsequent paragraphs. Certain general terms, used frequently in this chapter, which are necessary to an understanding of all remaining material are given below:

Concentration

Concentration is the amount of war gas or screening smoke present in a given volume of air. Concentration may be expressed in milligrams per cubic meter (mg m3), milligrams per liter (mg 1), or ounces per 1,000 cubic feet (oz 1,000 cu ft). Milligrams per liter and ounces per 1,000 cubic feet are almost identical numerically. Concentrations of war gases rarely exceed 1 per cent (by volume) in field areas.

Dosage

Dosage is the total concentration (C) of war gas to which a man or animal is subjected, multiplied by the length of exposure (t). Time, or t, is usually expressed in minutes (min). The CT product is usually expressed in milligram minutes per cubic meter (mg min m3). Dosages may be disabling or lethal. A lethal dosage is the amount of war gas per given volume of air, necessary to kill an average unprotected man. Exact figures for both disabling and lethal dosages depend on the kind of gas and the weather conditions.

Contamination

Contamination is the state of being covered, or act of covering something with chemical agents so that it is dangerous to touch.

Decontamination

Decontamination is the process of making any object or area safe for unprotected personnel by absorbing, destroying, or making harmless the war gases clinging to, or around it. In general, only areas or materiel contaminated by persistent gases need be decontaminated, since nonpersistent gases are quickly diluted to below dangerous concentrations.

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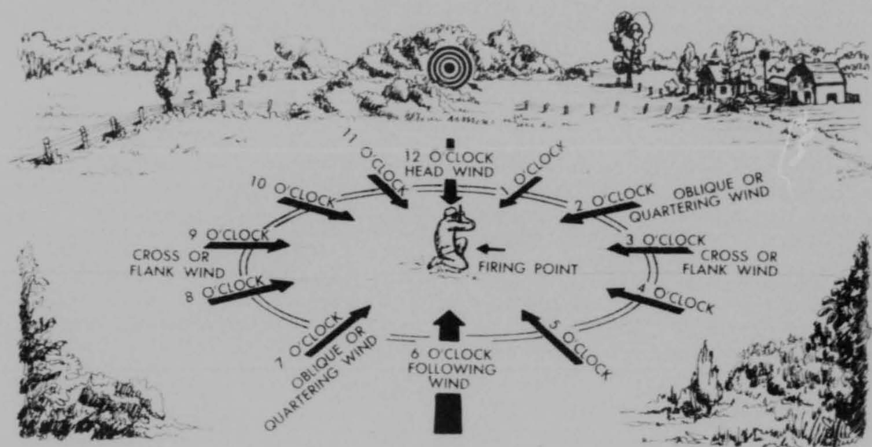


Gas Casualty

A gas casualty is an individual who has been affected sufficiently by chemical agents to render him incapable ot performing his military functions or duties.

Atmospheric Stability

Atmospheric stability is a term describing air conditions. When there are many rising and falling air currents, the atmosphere is said to be unstable. When there are very few or none of these currents, the atmosphere is said to be stable. The rising and falling air currents are caused by thermal or mechanical turbulence.

Thermal Turbulence

Thermal turbulences are atmospheric conditions resulting from thermal conditions (inversion, neutral, or lapse).

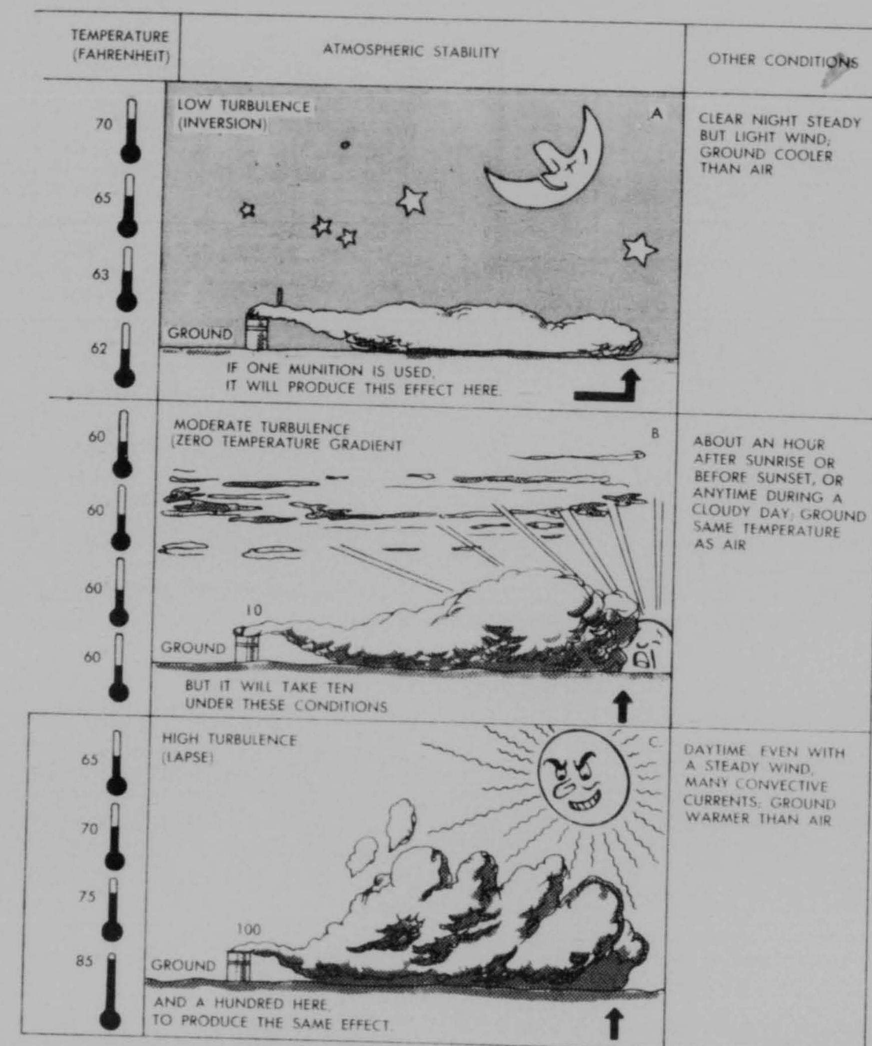
Inversion. On clear nights with a steady but light wind, a condition exists in which there is an increase in temperature with increasing height above the ground. Air currents are at a minimum, and thus there are stable atmospheric conditions near the ground. This condition favors the use of nonpersistent gas. Inversion conditions tend to be destroyed in wind speeds exceeding six to eight miles per hour over most types of terrain. Over very rough terrain, inversion conditions may be overcome by wind speeds lower than six to eight miles per hour.

Neutral. On heavily overcast days or overcast nights (and during the first hour after dawn and the hour before sunset), a condition exists in which there is very little or no change in temperature with height above the ground. There are few extensive rising or falling air currents, and thus there are moderately stable atmospheric conditions near the ground. Neutral conditions are only moderately favorable for the use of nonpersistent casualty gas.

Lapse. On clear or partially cloudy days, a condition exists in which there is a decrease in temperature with height above the ground. Air currents are at a maximum, and thus there are unstable atmospheric conditions near the ground. Lapse conditions may be modified in wind speeds over twelve miles per hour.

Mechanical Turbulence

Mechanical turbulences are atmospheric conditions resulting from terrain conditions. When air moves over a surface, many small eddies result. The rougher the surface, the more eddies exist, and the more unstable the



EFFECT OF TURBULENCE ON GAS AND SMOKE

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EFFECT OF WEATHER ON NONPERSISTENT GASES

FACTOR	FAVORABLE	AVERAGE	UNFAVORABLE
Sky	Clear night	Cloudy night or day	Clear day
Turbulence	Negligible	Slight	Marked
Wind direction	5-6-7 o'clock	3-4; 8-9 o'clock	10-11-12-1-2 o'clock
Wind speed (mph) Front line	3-8	8-12	over 12
Rear area	0-5	5-12	over 12
Precipitation	None	Slight	Heavy; steady
Humidity	Immaterial		
Temperature	Immaterial		

EFFECT OF WEATHER ON PERSISTENT GASES

FACTOR	FAVORABLE	AVERAGE	UNFAVORABLE
Section 1. For persistence of liquid			
Temperature (surface) °F. -H	45-60	60-70	over 70
-L	0-20	20-50	over 50
Wind speed (mph)	0-5	5-10	over 10
Wind direction	Immaterial *		
Section 2. For high vapor concentration			
Temperature °F. (surface)	over 100	70-100	less than 70
Wind speed (mph)	0-5	5-8	over 8
Wind direction	Immaterial *		
Humidity **	80-100	60-80	less than 60

* If more than 600 yards away from the contamination.
** Humidity has no effect on the agent itself but a high humidity renders personnel more susceptible to blister vapors.

EFFECTS OF WEATHER ON LATERAL SCREENING

FACTOR	FAVORABLE	AVERAGE	UNFAVORABLE
Sky	Clear night	Cloudy night or day	Clear day
Turbulence	Negligible	Slight	Marked
Wind direction	2-3-4; 8-9-10 o'clock	5-6-7 o'clock	11-12-1 o'clock
Wind speed (mph) WP	13-20	8-12; 20-25	less than 8; over 25
FS, FM, HC	5-12	3-5; 12-15	less than 3; over 15
Humidity - %	75-100	40-75	less than 40
Precipitation	Immaterial *		

* Even though rain may wash some smoke from the air, the presence of rain reduces visibility sufficiently to make up for it.

EFFECTS OF WEATHER ON AIR DEFENSE SCREENING

FACTOR	FAVORABLE	AVERAGE	UNFAVORABLE
Sky *	Clear day	Cloudy day or night	Clear night
Turbulence	Marked	Slight	Negligible
Wind speed (mph)	8-15	5-8; 15-20	less than 5; over 20
Wind direction **	5-6-7 o'clock		
Humidity	Immaterial		

* Refers to effect on screen. Thick low clouds might make a screen unnecessary and such a condition would then be favorable.
** Generators will be placed so a following wind will be obtained.

atmosphere becomes in the layers near the surface.

2. TACTICAL USAGE

Gases, smokes, and incendiaries should be used on targets particularly suited to each agent. They may be used alone or in conjunction with high explosives (HE). Employment of chemical agents should conform to the general principles for the use of any munitions in combat operations. Of these general principles, surprise, mass, coordination, and simplicity are most important. Although specific details of enemy tactics cannot be foreseen, reasons for using chemicals in combat can be stated. In general, war gases are used for:

Casualty Attacks

These are surprise attacks in which high concentration of war gases are built up in a short space of time (two minutes or less) on an area occupied by personnel to obtain a maximum number of casualties. Surprise is essential, since trained and well-disciplined troops minimize the results of such attacks. Usually nonpersistent agents are employed although persistent agents may be used.

Harassing Attacks

These are prolonged attacks in which a concentration of war-gas vapor is maintained in a specified area to force troops to wear gas-masks and to take other protective measures. Nonpersistent war gases may be used. However, it is more likely that persistent agents will be used because of the economy of munitions and the added inconvenience, delay, and danger due to contamination.

Neutralization Attacks

These attacks employ persistent agents to

force troops to evacuate areas or abandon materiel, to interdict strategic points by utilization of chemical barriers or to make supplies unusable. A determined enemy may elect to remain in contaminated areas or to cross chemical barriers, basing his decision upon certain calculated risks.

3. EMPLOYMENT OF CHEMICAL AGENTS

The characteristics and field behavior of each group of chemical agents dictate when and how the group probably will be used in field operations. It is not possible to anticipate accurately when and how an enemy will use chemical attack. A knowledge of when, and under what conditions, chemical agents can be most effectively used by the enemy, however, generally enables commanders to anticipate chemical attack.

4. NONPERSISTENT WAR GASES

Nonpersistent war gases are normally used on large groups of personnel to kill or disable. These gases generally are placed on targets very quickly and in high concentrations so that large percentages of troops are exposed to casualty-producing dosages before they have time to mask. Nonpersistent war gas is more likely to be used offensively than defensively because troops on the defensive are more likely to remain static. Weather conditions which are in general most favorable for the use of nonpersistent war gases consist of wind speeds below twelve miles per hour and inversion conditions. Wind speeds of approximately five miles per hour are most favorable. These gases are not likely to be used in heavy rains. Heavily wooded terrain is more favorable for the use of nonpersistent war gases than open areas, although some of the gas is absorbed by the foliage. Concentrations attained in woods or jungle may be three times higher than those in the open. Concentrations of nonpersistent war gas are higher in valleys and depressions than on hills and slopes. Thus, nonpersistent gases may be encountered in low places or in heavy woods.

CHEMICAL BOMBS
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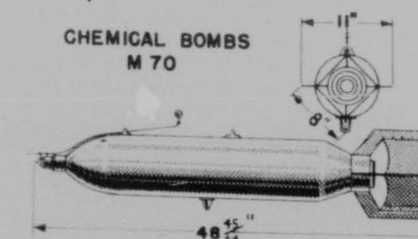


Use by Air Forces

Nonpersistent war gas may be dropped from the air in large bombs. This type of attack is especially dangerous because large quantities of gas can be released in very short periods of time. Air chemical attack is not limited to combat areas, and is likely to be launched against strategically important targets. In nonpersistent gas attacks laid down by air bombs the sudden expansion of a large quantity of agent to form a cloud produces a cooling of the surrounding atmosphere to form an artificial "inversion" condition. Hence, nonpersistent gas attacks by air drop are not affected by weather to the same degree as those in which ground chemical munitions are employed.

5. PERSISTENT WAR GASES

Persistent casualty gases are used against troop concentrations for casualty effect or on materiel and terrain targets to restrict use through threat of casualties. Most blister gases can be used for producing casualties through liquid contact or through exposure to vapor. Persistent casualty gases may be effectively used both offensively and defensively. There are more possibilities, however, for defensive use. Persistent casualty gas is most effectively used in hot, humid climates because the body is much more sensitive to these gases under such conditions. Persistent casualty gases may be used in wind speeds up to fifteen to twenty miles per hour, but higher wind speeds do not necessarily preclude the use of these gases. Inversion conditions are most favorable for the use of persistent casualty gases, and high vapor dosages may be expected under inversion conditions. Ground temperature is an important factor in determining how long a persistent casualty gas persists and how fast effective vapor dosages are attained (that is, the higher the ground temperature, the shorter the persistency and the faster effective dosages are attained). Heavy rains are unfavorable to persistent gas attacks. It can be very effectively used, however, during light rains or immediately after heavy rains. Contaminated vegetation is more hazardous than contaminated bare ground. Persistent casualty gases, therefore, are more likely to be used on vegetated targets. Thick woods and jungle are excellent persistent casualty gas targets, and very high vapor dosages may be attained on such targets. Thick jungle or forest canopy is a good cover from airplane spray; therefore, spray attacks are not likely to be made on heavily wooded or jungle targets, but bomb attacks set up high vapor dosages in such areas.

Use by Air Forces

Persistent casualty gases may be released from airplanes in large burster-type bombs or as sprays from spray tanks. Spray is essentially used directly against personnel. Because of its short persistency, it rarely is used on terrain targets. It should be noted that while the USAF does not consider spray tanks as the most effective method of dispersing blister gases (and does not use them for this purpose) other major world powers include spray tanks as a munition for dispersing blister gases. Burster-type bombs may be used either against personnel or on terrain. High vapor dosages are attained quickly when persistent casualty gases are laid down by burster type bombs or spray.

6. HARASSING GASES

These are used to handicap troops in carrying out missions by forcing them to wear masks or take gas-protective measures. Tear or vomiting gases, or light concentrations of nonpersistent or persistent casualty gases can be used for this purpose. Harassing attacks are usually made against troop concentrations. Tear gases may be dispersed from mortar or artillery shells, tear gas pots, grenades, bombs, or sprayed from spray tanks. Irritant smokes are usually dispersed from candles or pots.

7. SMOKES

Smoke screens and blankets are used to hinder observation and thus to hamper operations, reduce effectiveness of fire (including bombing), or reduce ability to meet an attack. In addition to its smoke effect, WP may be used for casualty effect. Smoke may be used in conjunction with casualty attacks to conceal the presence of gas. Smoke can be expected to be used under almost any weather condition. It is most likely to be employed in wind speeds under fifteen to twenty miles per hour.

Use by Air Forces

Air forces can lay smoke by using bombs or by spraying. Thus, observation points located beyond the range of ground weapons, as well as antiaircraft weapons, can be objectives of smoke missions.

8. INCENDIARIES

These are used primarily to destroy flammable materiel, but they may be used to kill, disable, or demoralize personnel, and for defoliation of camouflaged installations. The use of incendiaries in high winds tend to spread rapidly and are usually difficult to extinguish.

Use by Air Forces

Incendiary bombs of various sizes and types may be dropped on tactically or strategically important flammable installations. These bombs may be of a type which burn at extremely high temperatures and are difficult to extinguish. Highly flammable liquids in thin-cased containers may be dropped on troop concentrations and field fortifications and ignited.

9. EFFECTS OF WEATHER

Weather is an important factor in determining the field behavior of gases both from an

offensive and defensive standpoints. The following table shows the effect of various types of weather upon war gases:

Weather Elements	Favorable	Unfavorable
Winds	Weak	Strong, gusty
Temperature	Between 32° & 65°	Higher than 65° or below 32° F
Cloudiness	Overcast low, stratus type clouds	Cumulus or thunder clouds
Visibility	Poor	Good
Precipitation	None or light drizzle	Heavy rains
Season	Spring, autumn	Summer, winter

10. STRATEGIC IMPLICATIONS OF CHEMICAL WARFARE

Strategic air chemical missions are large-scale operations carried out by multiple units of heavy aircraft. These missions are usually executed in enemy rear industrial areas and are not in conjunction with actual operations on the ground. The targets are determined by higher headquarters and are assigned a regular priority. The detailed planning and execution of current air chemical operations are the joint function of the Director of Operations and Training and the chemical officer. The chemical officer advises the Director of Operations and Training so far as the chemical phase of the operation is concerned. It is the responsibility of the chemical staff officer to advise the Director of Operations and Training as to the best munitions and methods for carrying out the air chemical mission. Generally, the chemical staff officer is responsible for the following:

a) Calculating munition requirements.

b) Making certain that the munitions are available.

c) Insuring that chemical service troops are available when needed.

d) When requested, briefing pilots on any special phases of the chemical mission; for example, suggesting optimum altitude and method of release for persistent gas missions, or answering any questions regarding problems of handling and releasing chemical agents.

e) Notifying higher staffs of the mission.

f) Following up the results of the mission and reporting results to the next higher air chemical staff.

SECTION III—MUNITIONS MATERIEL

1. CHEMICAL MUNITIONS

There is a wide variety of chemical warfare munitions and allied equipment. This includes aircraft bombs; aircraft smoke tanks; such ground munitions as flame throwers, smoke generators, grenades, smoke pots and land mines; and the equipment necessary for handling such munitions. Certain chemical warfare munitions are filled just prior to use in the field. This filling, handling and loading work, formerly done by Chemical Corps units, is now a responsibility of USAF armament personnel.

2. BOMBS FOR AIRCRAFT

Chemical, smoke and incendiary bombs, presently standardized for use, are covered in chapter 7, vol. II. Significantly, however these bombs, in common with all chemical warfare munitions, are marked to conform with their tactical classification and persistency. The code used for this marking is indicated in Figure 7-1.

3. AIRCRAFT SMOKE TANKS

Aircraft smoke tanks (interchangeably called spray tanks) are devices which, when mounted on aircraft, may be used to spray liquid substances in the form of vapor clouds. At present the USAF uses these tanks only for laying smoke screens in support of ground operations, although they may be used for

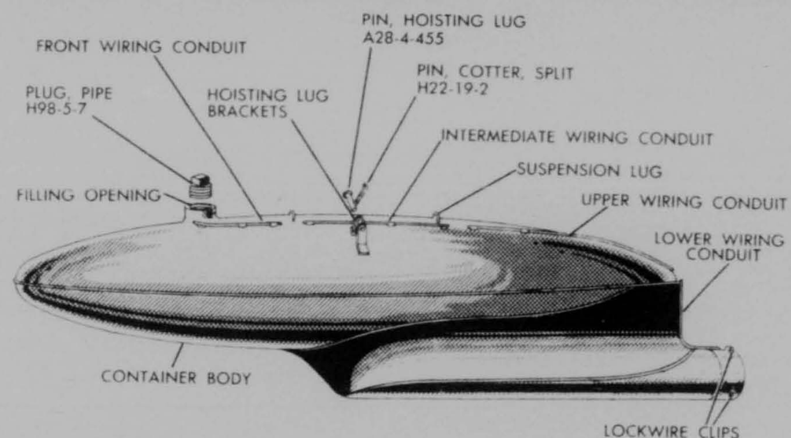


Figure 7—4. Exploded View of Container Assembly M10APST.

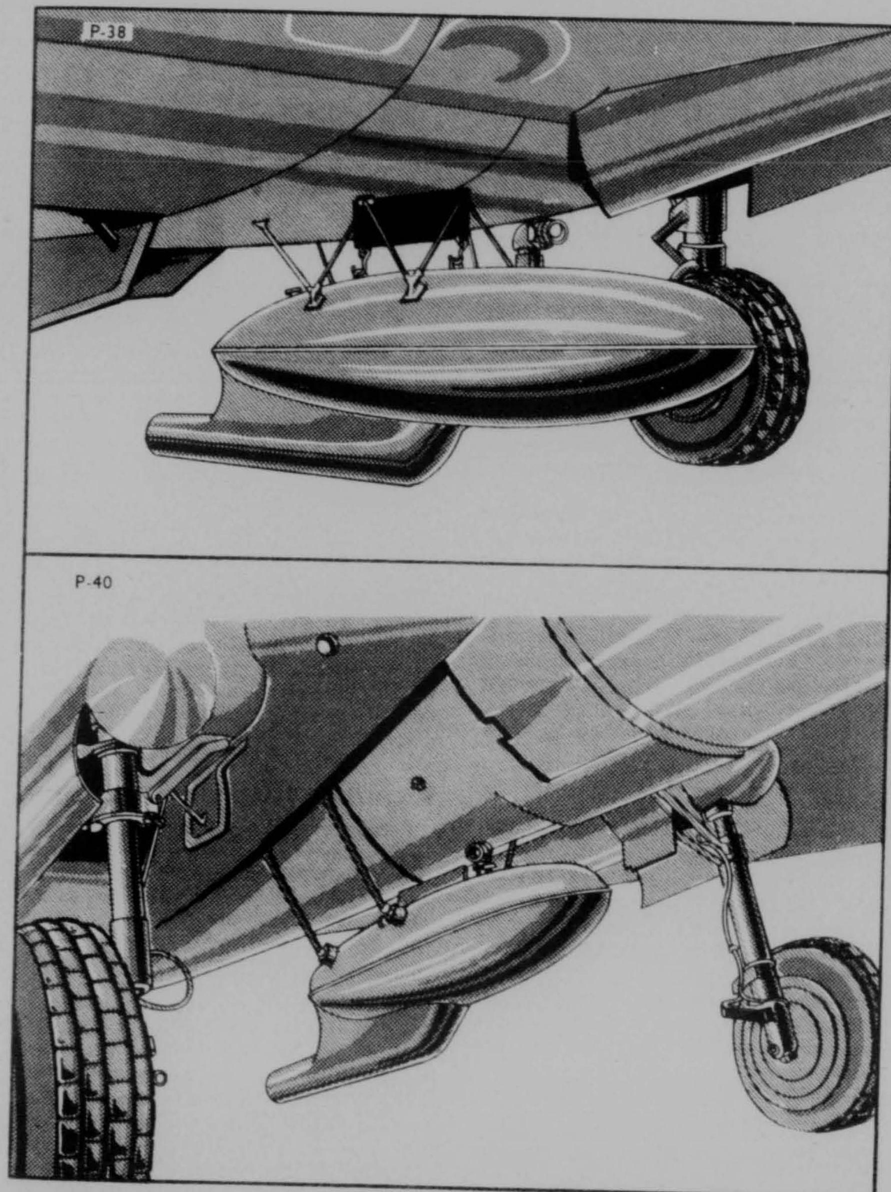
blister gases, tear gases and crop agents. Two types of smoke tanks exist; one for external mounting only and the other for external or bomb-bay mounting. These tanks operate by gravity flow, assisted by air pressure when a discharge plate is ruptured. Smoke tanks are not filled until just prior to loading aboard the aircraft. At present FS is the only smoke agent standardized for use in smoke tanks. In time of peace or training, tanks are retained on the aircraft, after discharge, and reused but in time of war externally mounted tanks are jettisoned on enemy territory after discharge.

4. M10 AIRCRAFT SMOKE TANK

This tank is designed for external mounting on fighter-type and light-bomber-type aircraft. It is a streamlined, cylindrical tank with an effective capacity of 30 gallons and a filled weight of about five hundred fifty pounds. The M10 tank consists of three main parts; a container, an air inlet assembly and a discharge line. As indicated in Figure 7-4, the container is completely sealed by means of closure plates prior to discharge. Contents of the tank are released by exploding detonators (blasting caps) fastened to the closure plates. This releases the filling, and gravity, assisted by a current of air entering through the air inlet assembly, forces it out through the discharge line. Discharge requires about six seconds during which an effective smoke curtain of about five hundred yards length can be established. This curtain will remain effective from one to four minutes depending on wind conditions. Other equipment used with these tanks include an M2 stand and an accessories set which contains a resupply of expendable closure plates, gaskets, grease and other items.

5. AN-M33A1 AIRCRAFT SMOKE TANK

The M33 smoke tank is suitable for use in bomb bays or beneath bomb-bay-type aircraft. This tank has an effective capacity of 70 gallons which, with all auxiliary equipment attached, brings its installed weight up to about 1350 pounds. A complete unit consists of the tank body, closure plate assembly, discharge line (composed of one or two sections), discharge line clamp and insulating jacket. Operation of this tank is exactly the same as for an M10 tank. Time of discharge is about eight seconds during which a smoke curtain seven hundred yards long can be established. Effective duration of curtains established with this tank vary from one to six minutes depending on wind conditions. Auxiliary equipment used with this tank is the M6 stand and an accessories set which contains a stock of expend-



M 10 TANK MOUNTED ON P-38 AND P-40

able closure plates, detonator retainers, gaskets, grease and nuts.

6. CHEMICAL CONTAINERS

Special containers are used for the storage and shipment of chemical agents. These containers range in size from one-ton containers to fifty-pound cylinders, each of which is used for specific kinds of chemical agents.

Ton Containers

These are of three designs, known as types A, D and E, and are used for storage and bulk shipment of casualty agents. A container weighs about thirteen hundred pounds empty and will hold a maximum of twenty-six hundred pounds of agent. Type D containers have large eduction tubes and are used for nonpersistent gases; while type E containers are all-purpose and may be used for any chemical agent. Special valves, valve wrenches and valve replacement mechanisms are required for use with these containers.

Drums

Light steel drums of 55-gallon and 110-gallon capacity are used for storage and shipment of harassing agents and screening smokes. Drums are equipped with one or two bungs, depending on the nature of the agent for which used.

Cylinders

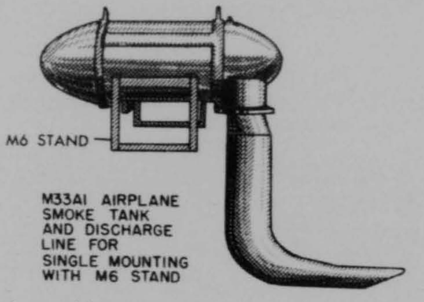
Cylinders of 50-pound, 75-pound and 150-pound capacity are used for shipping small quantities of chemical agent for training purposes.

7. CHEMICAL FILLING EQUIPMENT

Field filling operations are conducted with a variety of lines and pumps. Although each is designed for specific uses, several parts of the apparatus can be adapted for general field filling purposes. Filling equipment may be improvised from standard pipe fittings, valves, and flexible metal tubing.

Filling Line, M3

The M3 filling line is a flexible metal hose with valves, calibrated adapters and interchangeable nozzles which is designed for filling aircraft smoke tanks. These lines operate by gravity flow.



Smoke Tank Pump, M2

This apparatus is used to transfer liquid chemical agent from drums to smoke tanks by means of pumping instead of gravity flow. It embodies a special safety feature to prevent the escape of fumes during the filling operation, lines being provided both for filling and venting. Air and vapors displaced by liquid entering the smoke tanks through the filling line are forced back through the vent line to the bulk container, which is not open to the air. Thus no agent is released into the atmosphere.

8. CHEMICAL HANDLING EQUIPMENT

Certain special purpose vehicles and auxiliary equipment are provided for lifting and moving bulk containers, for moving aircraft smoke tanks and for field filling operations. The equipment includes:

Chemical Service Truck, M1

This truck is designed to carry drums or a ton container and field filling equipment. Removable compartments contain the filling equipment, protective clothing, decontamination equipment and first aid kits. An overhead rail contains a $1\frac{1}{2}$-ton hoist for moving containers. To use this hoist requires a hoist sling for drums or M2 hoisting beam for "ton" containers, both of which are included with the unit equipment.

Chemical Trailer, M1

The M1 Chemical trailer is used to transport 55-gallon drums. Two overhead rails, each equipped with a $\frac{1}{2}$ ton hoist, make it possible for one man to load or unload with ease. Due to its limited application, this trailer is obsolete but large numbers are available for use.

Chemical Handling Trailer, M2

The M2 trailer is used to transport either six filled 55-gallon drums, four filled 110-gallon drums, one filled ton container, two empty ton containers, eight filled M10 smoke tanks, or four filled M33 smoke tanks. Movable chocks are adjusted as necessary.

Swing Boom Crane Truck, M1

This unit is designed primarily for moving ton containers during field filling operations. The extension type boom can be moved right or left, up or down and the hook can be raised or lowered. Hook capacity with the boom extended is 3600 pounds.

Tank Loading Stand, M1

This stand is a tripod assembly fitted with a hoist. It is used to hoist 55-gallon drums during field filling operations.

9. FLAME THROWERS

The flame thrower is a weapon used by ground combat units for reduction of strong points and field fortifications. As such it is not used by the USAF for combat purposes. It may be used for certain auxiliary purposes such as clearing contaminated vegetation. There are two types of flame-throwers: portable and mechanized. Mechanized flame throwers are integral equipment on certain tanks and, due to nonrestriction on weight, have a very large capacity. Portable flame throwers are designed for portage by one man. Fuels used for flame throwers may be either of liquid or thickened type. This fuel is propelled to the target by highly compressed nitrogen, air or hydrogen gas.

10. FUEL MIXING AND TRANSFER EQUIPMENT

Thickened fuel consists of a specially prepared gelatinous or glue-like mixture of fuel thickener and liquid fuel. This thickened fuel is prepared prior to use in the field by means of a special kit. The presently standard unit is known as an M1 Mixing and Transfer, Thickened Fuel, Kit. Designed for preparing thickened fuel and transferring it to fire bombs, the unit contains an air compressor, air and fuel hoses, fittings, valves and air-agitation tube assemblies. Fifty-five gallon steel drums are required for mixing containers. One fire bomb requires the contents of four 55-gallon drums of thickened fuel.

11. SMOKE GENERATOR MATERIEL

In addition to aircraft smoke tanks, smoke screens may be generated by the use of mortar shell, artillery shell, smoke pots and smoke generators. Smoke pots and smoke generators may be used by USAF personnel for defense purposes. Hand smoke grenades and rifle smoke grenades are used in ground combat for blinding strong points.

Mechanical Smoke Generator, M2

The M2 Generator is a small size, lightweight device which is used, alone or in conjunction with other smoke-making devices, to produce large area smoke screens. The unit may be transported on one-quarter ton trailers, one-quarter ton trucks, boats or may be mounted on the ground. Movement of the unit while operating does not impair its efficiency. It produces smoke by forcing a mixture of fog oil (SGF) and water into a furnace assembly, where the two liquids are vaporized and then ejected in the form of a steam that condenses into thick white fog in the air. Fuel consumption is about sixty gallons per hour of fog oil. A smoke generator unit using 48 M2 generators can place an obscuring blanket of smoke over an area approximately $2\frac{1}{2}$ miles wide and from 8 to 15 miles long, depending on terrain and weather conditions.

12. CHEMICAL AGENT TRAINING EQUIPMENT

To assist in training individuals to recognize and identify chemical agents, certain kits have been developed. These units include:

Instructional Gas Identification Set

These units, called "sniff sets", consist of bottles which contain harmless concentrations of certain war gases absorbed in charcoal. By sniffing the air around the bottle's mouth it is possible to determine the odor of a specific agent. Two sets are presently standardized. The M1 set contains H, L, CG, PS, DM and CN, while the newer M2 set contains H, HD, L, PS, DA, AC, CG and CN. Either is suitable for classroom usage.

Detonation Gas Identification Set

This set is for field identification tests of war gases. Each unit contains four one-ounce tubes of H, L, PS and CG (sixteen tubes) in liquid solution and blasting caps for detonation purposes. The contents of a tube is detonated into the air and personnel then move through the gas cloud formed, noting the odor and appearance. An accessories kit is issued for use in preparing and firing the tubes.

Toxic Gas Set

The toxic gas set provides small quantities of liquid H for contamination and decontamination exercises, sensitivity tests on personnel and other training purposes.

13. FIELD LABORATORIES

The chemical laboratory unit, in functioning for the Chemical Corps devotes its efforts to surveillance of Chemical Corps materiel and to examination of enemy chemical-warfare items. In addition, it performs such functions for the other arms and other services as they may request. As a part of its work for the Air Forces, the laboratory unit analyzes materiel for indications of sabotage; tests cooling-liquids for aircraft motors, parachute silk, and cleaning mixtures; and makes investigations of corrosion inhibitors.

14. GAS CHAMBER MATERIEL

In succeeding paragraphs the military gas mask will be discussed. It is necessary to test gas masks in an atmosphere of gas to insure correctness of fit and inspire confidence. This testing is carried out in gas chambers with CN and CL. To establish concentrations of CN in a chamber, small gelatine capsules filled with CN are heated with a tallow candle on an improvised stove. Chlorine also may be released from portable cylinders.

SECTION IV—DEFENSE AGAINST CHEMICAL ATTACK

1. SCOPE

Defense against chemical attack begins with individual defensive measures and progresses to collective and tactical defensive measures. Both individual and collective protection involve the provision and use of protective equipment and installations. Tactical protection involves tactical plans and measures undertaken to lessen the probability, or security, of chemical warfare attacks.

2. ORGANIZATION

Training is a function of command. Unit commanders are responsible, therefore, for training their command in defense against chemical attack, for provision and inspection of protective equipment and for decisions as to the employment of collective protective measures in operations. To assist a commander in discharging his responsibilities, each unit has specially trained unit gas personnel. These personnel normally conduct the chemical training of their unit and are key personnel in the chemical defense plan. Within this framework, it is the individual's duty to protect himself against chemical attack. At higher command levels, staff armament officers specially qualified in chemical warfare are assigned.

3. PROTECTION

Defense against chemical attack begins with effective training. On this basis protection may be broken down into three phases: individual protection, collective protection and tactical protection. A unit commander is responsible for training his command in individual protection and for decisions as to the employment of collective and tactical protective measures. Within this framework it is the individual's duty to protect himself against chemical attack.

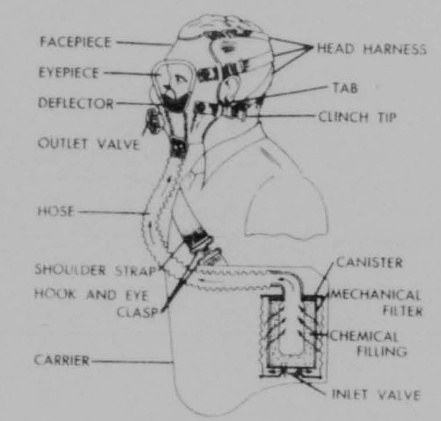
4. INDIVIDUAL PROTECTION

The first line of defense against chemical attack is individual protection. Individual protection involves the use of protective equipment such as gas masks, to remove agents from the air before they are breathed; and protective clothing, to prevent agents from coming in contact with the body. Coupled with this are first-aid measures which will be discussed later.

5. MILITARY GAS MASKS

Purpose

The military gas mask is an apparatus designed to purify the air which an individual breathes. Air is drawn into the mask when the airman inhales, and the mask is so constructed that this air must first pass through a canister containing a filtration system. This system comprises both mechanical and chemical filters, the former filtering out solid and liquid particles (smoke and dust), and the latter absorbing and neutralizing toxic and irritating gases and vapors. The air being purified by filtration is drawn to the face and after being inhaled and exhaled is expelled from the mask through an outlet valve. The facepiece fits snugly to the face so as to be gastight and is held in place by an elastic head harness. It is equipped with eyepieces of safety glass or other transparent material. It is also equipped with a deflector which deflects incoming air against the eyepieces so as to prevent condensation of moisture on the lenses, and in some types with a nosecup



M2A2 SERVICE GAS MASK

which prevents exhaled air from coming in contact with the lenses. In addition to this method of reducing dimming of the eyepieces, a soaplike substance (either in stick form or as an impregnated cloth), known as "anti-dim," is furnished with each mask (except the training mask) and which, when spread as a thin layer over the inner surfaces of the eyepieces, tends further to keep down eyepiece fogging. The facepiece is equipped with an outlet valve, through which exhaled air is expelled, and is connected to the canister by a corrugated rubber hose. The canister is a metal cylinder or oblong-shaped box containing a filter and chemicals comprising the filtration system. Ordinarily, it is equipped with an inlet valve which permits the entrance of incoming air and a nozzle for the exit of purified air. This inlet valve prevents exhaled air from passing through the canister. The nozzle of the canister usually is connected to the facepiece by the corrugated rubber hose tube through which the purified air passes to the wearer's face. The facepiece, hose and canister are contained in a canvas carrier.

Limitations

The protection afforded by the gas mask is due primarily to the canister, the other components of the gas mask merely preventing air from entering the facepiece by any other route. The filtration system of a military canister provides excellent protection against field concentrations of chemical agents. Generally, field concentrations are relatively low and do not exceed one per cent gas per volume of air. A canister does not supply or manufacture oxygen; gas masks therefore must not be used in an atmosphere containing less than sixteen per cent oxygen.

6. SPECIAL PURPOSE MASKS

Optical Gas Mask M1-1-5

The optical gas mask is designed for use with optical instruments, such as range finders, gun sights, field glasses, and periscopes, where the instruments must be held close to the eyes. It has small eyepieces made of plane glass. An adjustable bridge, called the eyepiece adjustment assembly, across the nose connects the two eyepieces so that the space between may be changed to correspond to the distance between the wearer's eye pupils, and thus permits him to focus and use binocular instruments requiring both eyes to be adjusted to the instrument eyepieces. There is a diaphragm in the mask to facilitate speech transmission. The canister is fitted to a head harness and when in use rests on the lower part of the back of the head so as to prevent interference by the hose with the operation of optical instruments. It is made only in the universal size.

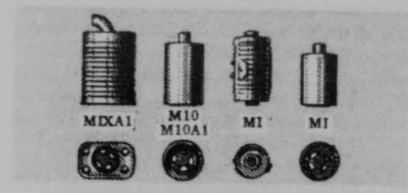
Aviators' Gas Mask

The aviators' gas mask, which is in the development stage and has not been standardized, has a fully molded rubber facepiece with eyepieces similar to those in the training mask. It contains a diaphragm to aid in speech transmission. It is so constructed that by means of a three-way valve the wearer can breathe oxygen from his oxygen tank, air that has been filtered through a canister, or unfiltered air. Thus, he can choose his air supply at will. It is made only in the universal size.

Paint Respirators

Paints, particularly the newer types of synthetics and lacquers, contain noxious constituents. Men engaged in paint spraying are subjected to the fumes of the volatile portions of these paints. Although spraying is usually done under a hood connected to an exhaust fan, some of the fumes almost always escape into the room. Since the human body can stand small amounts of these substances, only partial protection is necessary. The paint respirator covers the wearer's nose and mouth. It contains several layers of felt to stop pigment and liquid particles, and activated charcoal to catch some of the fumes. The eyes are not protected.

Protection from paint fumes should be provided in military establishments where spray-painting of vehicles and other equipment is required and no special ventilation is provided. Paint respirators to be used by the



SERVICE CANISTERS ISSUED TO THE ARMY

MVIII (substitute) a large disc-type inlet valve is in the bottom. "MVIII" is embossed on top of can.
MIXA1 a disc-type inlet valve is in the bottom. Corrugated body.
M10 or M10A1 - Smooth cylindrical body, inlet valve in bottom. The M number is embossed on top.
MI Optical - corrugated cylindrical body. Inlet valves in canister stems. Rain shield over inlet valve.
MI Training - not corrugated; straight nozzle; large inlet valve in bottom.

SPECIAL CANISTERS

1. All-purpose - red.
2. Hydrocyanic acid - yellow with white top.
3. Acid vapor - white.
4. Oil vapor - black.
5. Ammonia - green.

United States Air Force are of commercial types approved by the United States Bureau of Mines and are procured and issued by the Quartermaster Corps.

7. SPECIAL CANISTERS

Special canisters are designed for assembly with the standard service facepiece assemblies, M1, M1A1, M1A2, M2, or M2A1, or the standard diaphragm facepiece assemblies, M1, M1A1, or M11. It is also possible to use these canisters with the standard training facepiece M1, or M1A1, providing the standard 27-inch hose is employed. These canisters are to be used with carriers M111 and M111A1. The outer walls of all special canisters are made of tin plate with rounded corners and edges and are about 7 by 4½ by 3 inches. Each has an inlet valve in the bottom and each is connected to the hose by means of a canister nozzle or nozzle elbow. In order to recognize them readily, each type is painted a distinctive color as follows:

All-purpose	Red
Acid vapor	White
Hydrocyonic acid	Yellow w white top
All vapor	Black
Ammonia	Green

8. GAS CHAMBERS

Any reasonably airtight building of one or two rooms will serve for gas-chamber exercises. If such a building is not available, a pyramidal tent may be used. When using a tent for these exercises, it must be made as airtight as possible.

PHASE I

The chamber is filled with an effective concentration of tear gas (CN).

One CN capsule for each 100 cubic feet of space is used adding as needed to keep up concentration.

A heater is required to volatize capsules.

Gas-mask drill is conducted before men enter the chamber.

Ten men wearing masks enter the chamber and under the direction of an assistant, execute movements similar to those in combat.

Masks must not be tampered with while in the chamber.

When the men come out, the instructor moves the group up wind, inspects each mask for fitting, has each man remove his mask and inspects for signs of lachrymation.

Defects are noted and corrected, if possible, by adjusting the head harness, exchanging for a smaller facepiece, etc.

The masks are aired until all groups have gone through the chamber.

Personnel, upon emerging from the chamber, move up wind and face the wind before removing their masks.

PHASE II

Personnel should gain confidence in the protection afforded by the mask. This may be accomplished by the following procedure:

Men, properly masked, enter the gas chamber in which a strong concentration of CN has been generated.

After remaining in the chamber about one minute, each man in turn is told to take a position across the chamber away from the exit, remove his mask, and walk toward the exit.

An officer will be near the door to assist the men, if necessary, in leaving the chamber.

The officer should satisfy himself that each man becomes lachrymated.

Upon emerging from the chamber, the men are instructed to move up wind facing the wind, to separate and not form in groups.

Caution: Men must be instructed not to rub eyes as painful swelling may result. The men should wash their hands and face with soap and water as soon as possible.

PHASE III

Men who are properly masked enter the chamber where a high concentration of CN has been generated.

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They are instructed to test for gas.

They are cautioned to clear the facepieces. (In this way the men learn to detect gas and to properly clear the facepiece.)

The men then file out and face the wind as in Phase II.

PHASE IV

An assistant (junior officer or sergeant) takes his place inside the chamber.

Groups of three to six men will enter the chamber with the mask carried at the slung position.

The men hold their breath and, when at the far side, remove facepieces from the carrier and adjust them.

The assistant must emphasize the necessity of clearing the mask as the men adjust the facepieces.

The group remains in the chamber two or three minutes after adjusting the facepieces and then file out.

As the group emerges from the chamber, the officer inspects the adjustment of each mask while on the wearer before permitting removal.

Men must not touch or try to adjust masks before the inspecting officer sees them.

All adjustments to the mask should be made on the spot.

For those individuals who fail to pass the test, more preliminary drill is necessary and the test should be repeated until the desired proficiency is obtained.

9. PROTECTIVE CLOTHING

"Protective clothing" is clothing which has been impregnated with certain chemicals, and which, when worn as prescribed, affords protection against blister-gas vapor and very small droplets. It consists of two types: "permeable" protective clothing and "impermeable" protective clothing.

Permeable Protective (Impregnated) Clothing

Permeable protective (impregnated) clothing is special clothing which has been chemically treated. It affords a high degree of protection against the vapors and fine spray droplets of blister gases, since such small amounts of gases are rendered harmless when they come in contact with the clothing. This clothing does not protect against large droplets or splashes of liquid blister gases which may come in contact with the clothing when the wearer walks through heavily contaminated weeds, tall grass, or brush, or during decontamination operations of blister gases in liquid form. This clothing is issued as individual equipment.

PROPERLY ADJUSTED OUTFIT
Permeable Type

Impermeable Protective Clothing

Impermeable protective clothing is a coated fabric coverall-type suit which, when properly worn, affords complete protection to the wearer from the vapors and splashes of liquid blister agents. These liquid agents are shed by coated clothing in the same manner as rain is shed by a raincoat. During wear, body heat and moisture are held within the suit; consequently, it can only be worn for periods of approximately one-half hour by actively working men. Men working areas heavily contaminated with liquid blister agents should wear this type of clothing. Permeable protective long underwear is worn beneath the clothing. The impermeable protective clothing is issued as organizational equipment.

IMPERMEABLE TYPE CLOTHING
(Adjusted) FOR MEN

10. AUXILIARY EQUIPMENT

In addition to the gas masks and protective clothing, certain additional items of protective equipment are available. These include protective ointment and (BAL) eye ointment, eye shields, covers, and shoe impregnite.

Protective ointment is applied to exposed skin areas prior to exposure to blister gases and may be used for first aid treatment. BAL ointment is used for first aid treatment of eyes following exposure to blister gases.

Eye shields are designed to protect the eyes from liquid vesicants.

Protective covers fit over crouching individuals like an inverted sack and shield them from blister gas spray attacks. The top of the cover is transparent.

Shoe impregnite is applied to foot gear to prevent penetration of liquid blister gases.

11. PHYSIOLOGICAL EFFECTS AND FIRST AID

Blister Gases

Physiological effects of mustard gas and nitrogen-mustard gas on the eyes are:

Mustard gas (H) vapors cause no immediate symptoms; even the liquid is only mildly irritating at first. However in the first few hours the eyes become inflamed, smart, water and feel gritty, and are sensitive to light. The lids of the eyes then swell. In severe cases there is great pain, tears, and yellow discharge. In this case, permanent damage may result.

Nitrogen Mustard Gas (HN).

Nitrogen Mustard gas physiological effects are generally the same as mustard gas (H), but the damage from the more volatile forms of nitrogen mustard gas (HN) is more severe.

First Aid for the Eyes. BAL eye ointment should be applied at once, either for liquid or vapors severe enough to cause pain and spasm of the eye lids. If lids can be opened, the ointment should be squeezed directly into the eye and the lids massaged gently. If the eyes can not be opened, the ointment is applied to the closed eye and rubbed into the slits between the lids. As soon as the pain lessens and the eye can be opened, apply more of the ointment to the eye. Also rub the ointment on the eyelashes, lids, and skin around the eye.

If no BAL eye ointment is available, BAL eye solution (Item #5 in the Gas Casualty First Aid Kit) should be used. Two drops should be applied to the eyelids at once.

If no BAL eye ointment or solution is available, the eyes should be flushed with water immediately. Flushing is very helpful if done in the first minute after contamination, but valueless after two minutes. To flush, the face is held upward, opening the injured eye by pulling on the lower lid with one hand, and pouring water from a container held in the other. The patient should move his eye from side to side, and up and down. Washing should continue for one-half to two minutes. If no water is available, use urine or item #4 (eyes and nose Drops) from the Gas Casualty First Aid Kit.

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Physiological Effects on the Respiratory and Digestive System. Vapors of H or HN inflame throat and wind pipe if breathed. Mouth becomes dry, throat burns, and harsh, distressing cough develops. Partial loss of voice is common. Pneumonia may develop in severe cases.

Nausea and vomiting may follow severe skin contamination, especially in hot weather, even if a mask has been worn. This is a systemic effect not due to direct injury; swallowing of contaminated food or drink may cause inflammation of stomach, pain, and vomiting.

First Aid for the Respiratory and Digestive Systems. Liquid gas should be removed from the face immediately to prevent further inhalation of vapors. Contaminated clothing also should be removed. No other first aid is effective. The victim is treated as would be a choking-gas casualty; clothes are loosened, the patient should be kept quiet and warm, given warm (non-alcoholic) drink, and evacuated by litter. If no medical treatment is available and evacuation is impossible for twenty-four hours or longer, wound tablets, from the first-aid pouch, should be administered to prevent pneumonia.

Physiological Effects on the Skin. Injury begins with the reddening of the skin, like sunburn, and may be followed by blistering (under different climatic conditions, this varies with concentration and length of exposure). Liquid always blisters unless counteracting steps are taken at once. Normally moist skin areas are most affected (like bend of elbows and knees, armpits, and crotch).

Vapor is about one-fifth as damaging as H. Liquid forms blisters more quickly, but they are less severe.

First Aid for the Skin. Liquid must be removed and skin decontaminated within three minutes to avoid blistering. Contaminated clothing is removed. The skin is then blotted with absorbent material furnished with protective ointment, or with dry cloth. Care should be taken not to contaminate additional skin while blotting. Next, protective ointment from the tube, rubbing it on the affected area for about fifteen seconds. Excess ointment is wiped off. This procedure is repeated if the skin has been heavily splashed. Soap and water can be used as a substitute, or bleach paste (equal quantities of water and dry bleach) can be used if washed off within three minutes.

Ointment or bleach should not be used if skin has already reddened or begun to blister as it only increases the burn. Instead, calamine lotion (item #2 in the Gas Casualty First Aid Kit) should be used, following instructions given in kit. Vapor burns cannot be helped by first aid, the damage is already done, and neither ointment nor soap and water helps.

Liquid burns are treated with ointment in the same manner as H liquid burns. But ointment merely dilutes and does not destroy HN. Therefore, the film of ointment should be washed off with soap and water, preferably, or with water alone. Ointment should not be used if the skin is already red; instead, soap and water should be used. Vapor burns cannot be helped by first aid, since the damage is already done.

The Physiological Effects on the Eyes of Lewisite and Other Arsenicals (Ethyldichlorasine, Methylichlorarsine, and Phenyldichlorarsine).

The eyes are specially susceptible. Vapor irritates immediately; liquid causes instant, excruciating pain and spasm of eyelids. Unless first-aid measures are taken immediately eyes swell and inflame seriously within one hour, and may be permanently injured.

ED, MD, PD, act the same as Lewisite, but generally are less severe.

First Aid for the Eyes. BAL eye ointment should be applied, at once, either for liquid or vapors severe enough to cause pain and spasm of the eyelids. If the lids can be opened, ointment should be squeezed directly into the eye and the lids massaged gently; if not, it should be applied to the closed eye and rubbed into the slits between the lids. As soon as pain lessens and the eye can be opened, more ointment should be applied. It also should be rubbed on eyelashes, lids, and the skin around the eye. If no BAL eye ointment is available, BAL eye solution (Item #5 in Gas Casualty First Aid Kit) should be used. The eye is opened and two to four drops placed in it, and one or two

drops on the eyelids. Application should be made only once.

Physiological Effects on the Respiratory and Digestive System.

The physiological effects are the same for Lewisite as for mustard gas.

ED, MD, PD., is the same as it is for mustard gas, generally, but breathing very low vapor concentration may cause coughing, sneezing, pain in the nose and throat, nausea, and vomiting and distressed feeling.

First Aid for the Respiratory and Digestive System. First Aid for Lewisite is the same as it is for mustard gas.

ED, MD, PD., are generally the same for mustard gas (H), but after exposure to low vapor concentrations (producing symptoms like those of vomiting gas), nose and throat should be rinsed with water, and the patient kept quiet). Fumes of chloroform (item #1 in Gas Casualty First Aid Kit) may be inhaled to give relief in severe case, inhalation being repeated as required.

Physiological Effects on the Skin. The physiological effects of L, ED, MD, PD, are the same as they are for H, but liquid acts faster, penetrating skin rapidly and causing stinging sensation within one or two minutes; vapors are far less dangerous than H vapors.

First Aid for the Skin. Liquid is blotted from the skin immediately. If skin hurts, gas may be assumed to be an arsenical. Protective ointments are applied as described for mustard (H) burns (although it may not completely prevent blistering if weather is hot). Soap and water should be used if no better remedy is available. An attempt should be made to prevent blisters from breaking, leaving them for medical treatment. Vapor burns cannot be helped by first aid.

M-5 Protective Ointment. All references to protective ointment noted above apply to M-4 Ointment.

M-4 ointment eventually will be replaced by M-5 ointment, now in production. M-5 ointment is used exactly as M-4 ointment with these exceptions:

On applying M-5 ointment to contaminated skin, it is rubbed for thirty seconds, instead of fifteen seconds.

It should be left on the skin.

M-5 ointment is used before exposure to blister gas, as well as after. Using the entire contents of one tube, the ointment is rubbed in a smooth, even coating on unprotected skin areas. It is applied again whenever absence of the characteristic color (gray-green) indicates that the skin is no longer protected. Protection, by application before exposure, extends only to blister-gas vapor; if droplets fall on skin, decontamination must be accomplished as directed in the above.

Choking Gases

Physiological Effects. Symptoms vary considerably, but there is usually irritation of nose and throat, coughing, difficulty in breathing and pain in the chest, especially upon deep inhalation. Other possible symptoms are tears, vomiting and blueness of lips and ear lobes. Symptoms appear immediately only if exposure has been severe. They may persist and grow worse; but often first symptoms disappear, followed by latent period in which victim feels fairly well. Here serious symptoms of lung injury may not appear for several hours.

First Aid for Choking Gas Casualties. Mask should be kept adjusted until the area is free of gas. The airman should carry on if there are no immediate symptoms. But if there are immediate symptoms, institute first aid as soon as tactically possible. The clothing should be loosened, the airman should rest, and keep warm with blankets. Artificial respiration should not be given. Nonalcoholic stimulating drinks (not tea or coffee) should be given. The patient should be evacuated to an aid station by litter as soon as possible. The greatest danger for a choking gas victim is during the first forty-eight hours after exposure.

Blood and Nerve Poisons

Hydrocyanic Acid (Hydrogencyanide) or Cyanogen Chloride.

Physiological effects are highly toxic when inhaled.

High concentrations are fatal and the symptoms progress in the following order.

Labored breathing, convulsions, coma, and death.

Low concentrations may produce headache, dizziness, and nausea. First breath may be so stimulating to respiration that it is then impossible to hold the breath.

Liquid penetrates the skin and is toxic.

First Aid for Hydrocyanic Acid (Hydrogen-cyanide) and Cyanogen Chloride.

If the victim is in a closed place, he should be masked and moved into fresh air immediately; too great a concentration may penetrate the gas mask canister.

If he has stopped breathing, artificial respiration should be given until medical aid is available. Amylnitrite (item #7 of Gas Casualty First Aid Kit) may be used meanwhile. Crush and hold close to victim's nose or thrust inside facepiece if masked. This should be repeated at three to five minute intervals, meanwhile continuing artificial respiration.

If liquid gets on the skin, it should be washed with water or a weak solution of baking soda and water. Clothes containing liquid should be removed and aired.

Physiological Effects of Arsine. Mild cases causes lassitude, headache, and uneasiness.

Increased exposure causes chills, nausea, and vomiting.

Severe exposure damages the blood, causing anemia, and the victim's urine is brown or red.

First Aid for Arsine. The mask should be adjusted and the victim removed by litter to fresh air.

He should not be allowed to walk.

He should be hospitalized immediately.

Green Ring 3 or Tabun Gas

General first aid procedures outlined for treatment of war-gas casualties are effective for treatment of casualties resulting from this new blood and nerve poison. Liquid contamination must be treated immediately. Blotting the liquid and washing the contaminated area with slightly alkaline or acid water effectively removes the liquid gas.

Physiological Effects of Vapors. Vapors, even in low concentration, causes the pupil of the eye to contract. This makes it difficult to see in dim light and causes headache. After short exposure, a sense of tightness in the chest may be noticed, which is increased by deep breathing. Vapors, when inhaled, cause nausea and diarrhea.

Liquid does not injure the skin, but penetrates the skin and poisons the body.

First Aid for Green Ring 3 or Tabun Gas. The victim's mask should be adjusted and the patient removed to a safe area, if possible. If he has stopped breathing, artificial respiration should be given. If liquid gets on the skin, it should be blotted out and the contaminated area washed immediately with soapy water or flooded with water. All contaminated clothing should be removed and care exercised by the person administering first aid not to contaminate himself or other parts of the victim's body.

If liquid enters the eye, it should be flushed with water or a solution of sodium bicarbonate in water.

Vomiting Gases

Physiological Effects: Irritation of the nose and throat, often causing coughing, sneezing, and salivation. Pain in the nose, throat and windpipe is fairly intense; gums and teeth ache. Nausea and vomiting may occur, and the victim may feel very distressed. But there is little danger, and effects usually pass within three hours. Most victims can carry on strenuous duties without harm, and often with a more rapid decrease in symptoms.

First Aid for Vomiting Gases. The mask should be adjusted as long as gas is present in the atmosphere, removing it only briefly during periods of actual vomiting. It should be removed, shaken, and the outer clothing aired if the situation permits. The skin should be washed with soap and water. If symptoms persist, the nose and throat are rinsed with water. In extreme cases, the victim should be kept quiet until distressing symptoms have passed. Fumes of chloroform (item #1 in Gas Casualty First Aid Kit) should be inhaled, repeating as required.

Tear Gases

Physiological Effects: Acute pain in the eyes, profuse tears, and spasm of eyelids. There is usually no permanent damage, and effects wear off quickly; but temporarily the victim may find it almost impossible to see.

First Aid for Tear Gases. The eyes should not be rubbed as this only increases the irritation. The mask should be kept adjusted until the atmosphere is free of gas, then removed and the victim's face turned into the wind with eyes open. Skin areas which sting or burn, or on which liquid gas has been splashed, should be washed with soapy water. If liquid has entered the eyes, they should be flushed with plenty of water, or treated with eye and nose drops (item #4 in Gas Casualty First Aid Kit). Medical treatment or evacuation is not normally necessary.

Screening Smokes

Physiological Effects of Liquid Smokes. Liquids irritate or burn the skin. Smoke itself is usually harmless except in prolonged exposure; slightly irritating to respiratory tract.

First Aid for Liquid Smokes. Liquid should be washed from the body with water (preferably soapy). If the respiratory tract is irritated by smoke, the victim should be moved to fresh air when tactically possible.

Physiological Effects of Solid Smokes. Prolonged exposure without a mask irritates the nose and throat; may cause coughing and lung irritation.

First Aid fo Solid Smoke (HC). The victim should be removed to fresh air if tactically possible.

Physiological Effects of White Phosphorus. Smoke is harmless except in prolonged exposure, but burning particles cause severe burns.

First Aid for White Phosphorus. Affected skin area is immersed in water to extinguish burning particles. Air should be excluded from particles until they can be removed; otherwise, they will reignite. Particles should be wiped or brushed from the skin with a wet cloth (medical aid may be required for this). Copper-sulfate (item #3 in Gas Casualty First Aid Kit) should be to the burned area for several minutes. This coats the particles, keeping them from the air, and permits exposure of the burn without danger of fire. Particles can then be removed more easily, preferably with forceps.

12. COLLECTIVE PROTECTION

Collective defense against chemical attack includes equipment, installations, techniques used by the unit or by smaller groups for defense of personnel, animals, and materiel, against chemicals. It includes:

Detection devices.

Alarm systems and duties of sentinels.

Gasproof shelters and fortifications.

Protection of supplies and equipment.

Decontamination of food and water.

Decontamination of equipment, terrain, and buildings.

Personnel decontamination stations.

Organizational first aid.

Defense against incendiary attack.

13. DETECTION DEVICES

Various detection devices have been designed for both the detection and identification of war gases. These devices indicate the presence of war gas by a change of color. They are useful in indicating the completeness of decontamination, in determining the presence of war gas in concentrations too low to be detected otherwise, and in estimating the hazard of operations in contaminated areas.

Liquid Vesicant Detector Paint

Detector paint is effective only for spray or droplets, not for vapor. It is olive green, turning red when in contact with blister gases. Bleach, M4 decontaminating agent, protective ointment, and certain tear gas solutions give the paint a similar red color. The paint turns brick red at temperatures over 150° F. The paint is applied to fenders and hoods of vehicles on areas visible to the driver, or to other organizational equipment, and must be renewed frequently.

Liquid Vesicant Detector Paper

Detector paper is issued in booklets of twenty-five sheets. It is heavy paper coated with detector paint, which turns red when liquid blister gas touches it. It has certain field limitations. Like detector paint, it is affected by bleach and other materials even in the absence of war gas. It does not detect vapor. Heat, steam, or oil decrease its sensitivity, and it turns red when heated to approximately 150° F. It is unreliable in determining completeness of decontamination.

Chemical-agent Detector Kit

The detector kit reveals dangerous concentrations of certain war gases by color changes in tubes through which contaminated air is drawn and to which liquid reagents are added. Complete directions for use are included with each kit. All unit gas personnel and all special gas sentinels should be thoroughly familiar with the use of the kit, and the kit should be used whenever practicable or when any doubt exists.

The sensitivity of the detector tubes makes it possible to determine whether the air contains a dangerous amount of gas. In interpreting the results obtained by sampling air or vapors, personnel must be certain that samples are taken at several points, at frequent intervals, and in accordance with wind conditions. If a large enough sample of contaminated air is taken, the detector tubes are sufficiently sensitive to detect a concentration below that which is necessary to cause casualties. Low concentrations of phosgene which are detectable by smell, however, are not detected by the kit.

14. GAS SENTINELS

All sentinels have duties in connection with defense against chemical attack. Depending upon the tactical situation, special gas sentinels may be required for installations such as gasproof shelters, for protection of materiel, and for guarding contaminated areas. These should be detailed as required. Special gas sentinels are usually posted to warn troops against dangerous gassed areas and to protect supplies at distributing points. Their duties do not differ from the usual duties of gas sentinels except that they are given special instructions regarding specific duties. Special sentinels on duty where supplies are stored should have protective clothing. Such installations may be subject to frequent spray attacks. Since such attacks develop rapidly, the sentinel must be on the alert in order to get the supply covers into position. Covers should fold and be adaptable to quick spreading in case of attack. They should always be in position when practicable. If the attack is by incendiaries, the sentinel should give the prescribed fire alarm.

15. ALARM SYSTEMS

Two different types of gas alarms are given by the sentry—one for airplane spray attack, and one for all other methods of attack.

Alarm for Spray

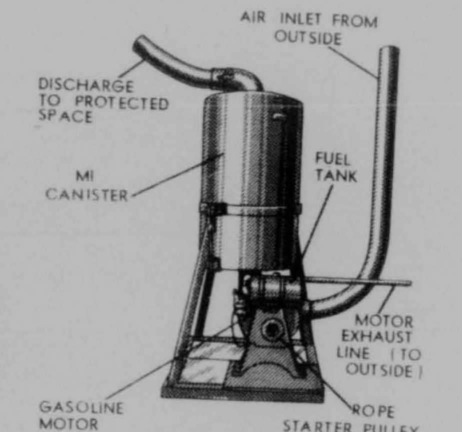
If the attack is by airplane spray, only the warning cry of "spray" is given. It should be given only when attacking aircraft are actually observed to begin a spray attack. The sentry then: Adjusts his protective cover and masks; follows SOP for defense against air attack (if firing, thrusts rifle or carbine forward through top corner of protective cover); resumes normal sentry duties.

Alarm for Other Types of Gas Attack

If the gas attack is by any other method, the sentry shouts "gas"; sounds the percussion alarm for a period of fifteen seconds, holding his breath, if necessary; adjusts his mask; resumes sounding the percussion alarm for one minute; awakens all personnel in the vicinity of his post; resumes normal sentry duties, but does not remove mask until the "all clear" order is given, or until the area is shown by test to be gas-free.

General Alarms

General alarms are sent out if large areas are involved. Such alarms are given by all normal methods of communication and embrace all areas likely to be affected. The procedure should be set forth in the unit standing operating procedure.



COLLECTIVE PROTECTOR M2

16. GASPROOF SHELTERS AND FORTIFICATIONS

Purpose

Since it is possible for an enemy attack to subject an extensive area to lethal concentrations of casualty war gas for periods ranging up to several days, some means of shelter must be provided for various types of field activities. Masks and protective clothing are sufficient protection against such concentrations, but they cannot be worn indefinitely, moreover, many essential functions cannot be performed satisfactorily while wearing such equipment. Gasproof shelters are needed, therefore, where troops can rest and eat during prolonged attacks, and where communications, command, and similar functions can be conducted without interruption. Field hospitals may also require gasproofing.

Types

If gasproof shelters are equipped with collective protectors, they are the ventilated type. If not, they are called "unventilated." Each shelter is posted with a sign giving this information, together with the capacity and length of time the shelter can be occupied. Either ventilated or unventilated shelters may be permanent, semipermanent, or improvised. Permanent and semipermanent gasproof shelters are built by the Corps of Engineers according to approved drawings. Improvised shelters, either ventilated or unventilated, are built in the field when the need arises. This section is concerned only with the field type of improvised shelter, which is usually built from structures or dugouts already in existence or easily and quickly constructed.

17. PROTECTION OF SUPPLIES AND EQUIPMENT

General

Chemical agents may damage supplies not adequately protected, both as a result of the original contamination and through acids formed by the hydrolysis of certain war gases. Moreover, supplies contaminated with blister gases are dangerous for personnel to handle or contact. Proper packaging and storing minimize the effects of chemical agents. Paulins or other covers are used over supplies stored outdoors. Paulins, used in pairs with a layer of tree branches between them, provide increased resistance to penetration of liquid agents.

Food

When possible, bulk food items are kept in closed containers (preferably moistureproof) and covered with paulins. The most vulnerable foods are placed in the least exposed positions. For protection against airplane spray, kitchen trucks are covered with paulins, and field kitchens are provided with tent flies or other overhead covers. Contaminated food is usually discarded, but instructions of the medical officer govern its disposal.

Water

Water is kept in closed containers. If Lister bags are used, they may be protected from liquid contamination by individual protective covers adapted to this purpose. The Medical Corps reports on the potability of water, and the Corps of Engineers purifies it.

Equipment

Ammunition is kept in its containers as long as possible.

Weapons are covered with protective paulins or dispersed under natural cover.

Instruments, such as those used for fire control, are kept in their containers when not being used. Both ammunition and instruments are subject to corrosion by such war gases as phosgene and such smokes as FS.

Airplanes are provided with covers (at least for cockpits, plastic windows, guns and gun compartments) when not in hangars.

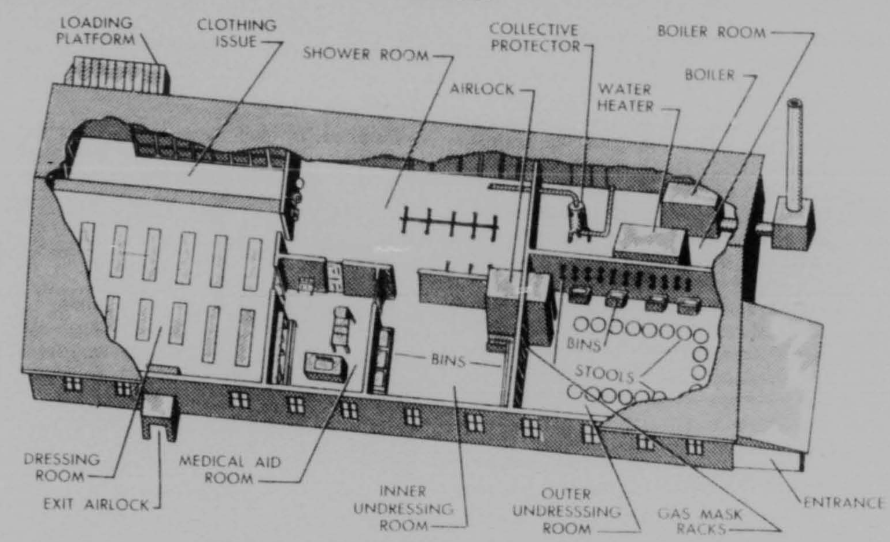
Automotive equipment is stored in woods free of underbrush, but lower portions of ravines and canyons are avoided. (Mobility of vehicles provides some degree of tactical protection.)

Flammable supplies, such as fuel, oil, and flammable munitions, are kept in containers until used.

18. DECONTAMINATION

General

Chemical agents may be destroyed or neutralized by other chemicals. No one chemical, however, is effective in all cases. Moreover, it is not practicable for an army to carry either a great variety or quantity of chemicals. Consequently, decontamination operations are necessarily limited. Whether they are practicable at all will depend upon the character of the chemical agent involved and the extent of the contamination. Other than ventilation, it is not worth while to consider destruction of agents having a low, or even moderate, persistency. Nature is the greatest decontaminator. These agents are soon dispersed by the wind. It is necessary, however, to provide for cleaning or disposing of supplies and munitions which may be affected by such agents. Persistent agents present a very different problem. Even small quantities of such



PERSONNEL DECONTAMINATION STATION

gases as mustard or Lewisite are dangerous. It will not be feasible to decontaminate large areas but there may be many cases where decontamination work is both practicable and highly desirable.

Personnel

Personnel detailed for decontamination operations should be trained for such work. They should wear gas masks and protective clothing covering the entire body. If necessary to use men who have had no training in such work, each squad at least should be under the supervision of an experienced noncommissioned officer. The supervising personnel should, in any case, have a sound knowledge of first-aid measures and should have the necessary medical equipment close at hand. The men should be inspected before commencing operations to insure that they are properly protected. Facilities away from other troops should be provided for undressing and bathing after completion of their work. Men should be taught to assist each other in removing protective clothing without touching it with the bare skin. Facilities for disposal or cleaning of contaminated clothing should be provided.

19. DECONTAMINATION AGENTS

There are a variety of materials which may be used for decontamination work. Some are more effective than others. The use of any single decontaminating agent is limited by its local availability at the time of use. Specific agents which may be used are:

Bleach

Bleach is a white powder which contains about 35 per cent available chlorine and is known commercially as chlorinated lime, bleaching powder, calcium bleach or chloride of lime. Bleach will destroy or convert H, L, ED, and HN into harmless or less toxic compounds by oxidation and chlorination. It reacts violently with liquid H, envolving much heat. Bleach is usually mixed with water or earth before being used in order both to increase its distribution and to diminish the heat of the chemical reaction with H. Although it is corrosive to most metals and injurious to most fabrics, it is the most commonly used decontaminating agent. Dry bleach may be applied directly to contaminated surfaces in situations where there is no objection to fire or vapor hazard.

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Noncorrosive Decontaminating Agent (DANC)

DANC is a light cream colored powder which, when dissolved in a solvent such as acetylene tetrachloride, is used for decontamination of H, L, ED, and HN. DANC is shipped in five gallon containers. It is one of the most effective decontaminating preparations known. It is easily prepared and will destroy most persistent vesicant agents in half an hour or less. Unfortunately, it is expensive, and its use must be limited to surfaces where bleach would be too corrosive. It is not entirely noncorrosive but considerably less so than bleach. DANC, a slightly noticeable residue which, however, is corrosive if left in prolonged contact with metal. Some disadvantages are its toxicity, its tendency to soften rubber and plastics and remove paint, and the formation of hydrochloric acid when the acetylene tetrachloride comes in contact with moisture.

Caustic Soda (Lye)

Caustic soda, or lye, the chemical name for which is sodium hydroxide, is a white solid which dissolves easily in water. Preparing solutions of lye liberates considerable heat and the containers should not be handled with the bare hands. It destroys most chemical agents on contact when moisture is present, and is especially effective in destroying Lewisite. Caustic soda does not destroy mustard gas as rapidly as does bleach.

Sodium Hypochlorite

Sodium hypochlorite is a commercial solution containing approximately fourteen per cent available chlorine. It liberates chlorine upon contact with persistent agents and converts them to less toxic forms. This agent is rapid in action but more corrosive than DANC.

Washing Soda

Sodium carbonate, known as washing soda, soda ash, sal soda and laundry soda is a white powdery substance with mild alkaline properties. Its action, due to a neutralization reaction, is quite slow but it is not corrosive to materiel.

Water or Steam

Water under high pressure or steam may be used to remove dirt or grease, containing embedded chemical agents, from surfaces. Water is most effective if hot and if soap or other detergent is used.

Fuels and Solvents

Fuels may be sprayed on contaminated areas and the area then burned off. Vapors generated by this method are dangerous, however, and personnel must remain upwind. Likewise precautions must be taken to avoid uncontrolled fires. The most common solvents used in decontamination are gasoline, kerosene, motor oil and acetylene tetrachloride. Solvents are applied in such a manner as to dilute and wash away chemical agents.

Inert Materials

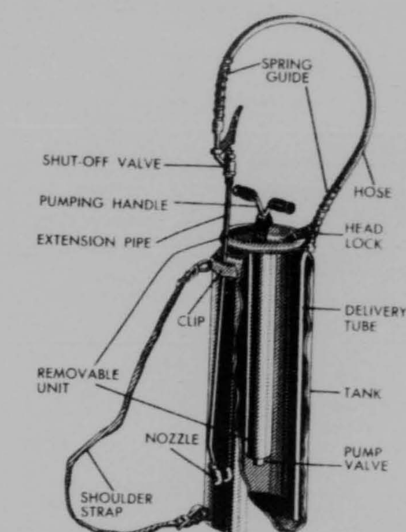
Earth, sand, ashes, soot, or sawdust may be spread over a contaminated area to give temporary protection. The covering layer should be at least three inches thick. It does not destroy the chemical agent but forms a seal preventing, for a limited time, the escape of toxic vapor. Such covering will be more effective if wet down with water.

20. DECONTAMINATION EQUIPMENT

Certain equipment is presently standardized for use in application of decontaminating agents to contaminated materiel. These include:

Decontaminating Apparatus (3-gallon)

The decontaminating apparatus (3-gallon) is a modified, commercial insecticide sprayer used for spraying contaminated equipment with DANC. The apparatus is carried empty and is filled with freshly prepared DANC immediately prior to use. It contains a pump which compresses air over liquid in the tank, thus forcing the liquid out through the dis-



DECONTAMINATING APPARATUS M1 (3 gallons)

charge line and nozzle. These apparatus are made by a number of manufacturers and will differ slightly in appearance and dimensions.

Decontaminating Apparatus (1½ Quart)

The decontaminating apparatus (1½ quart) is a standard decontaminating apparatus approximately eighteen inches long and three inches in diameter. There are two forms, the air pump type and the liquid pump type, which are similar in appearance. This apparatus is carried in all vehicles in the theater of operations for organizational decontamination. It also may be used to decontaminate small items of equipment. One filling of DANC will decontaminate up to twelve square yards of surface. The apparatus will project its filling about five feet in the form of a spray, the complete discharge requiring about ninety seconds.

Decontaminating Apparatus M3 (400 Gallon)

This apparatus is a modified commercial power-driven orchard sprayer consisting essentially of a wooden tank of 400-gallon working capacity with a rotary agitator, a piston type pump equipped with a pressure regulating unloader, or relief valve, capable of delivering approximately 35 gallons of mixture per minute at a working pressure of 400 pounds per square inch, and a power take-off unit which drives the pump and agitator by means of roller chains. The entire apparatus is mounted on a 2½ ton, six-wheel-drive, gasoline engine truck. It is assigned only to special personnel and is used for large scale operations, such as decontaminating roads, buildings, and other critical installations. It is filled with wet mix (bleach slurry), or with water and detergent (such as soap). One tank load contains sufficient agent to cover an area of approximately 1600 square yards.

Auxiliary Equipment

Other equipment which is used for decontaminating purposes includes swabs, rags, shovels, rakes and brooms. These are used for such purposes as mixing solutions, removing debris and applying solutions to very small objects or otherwise inaccessible places.

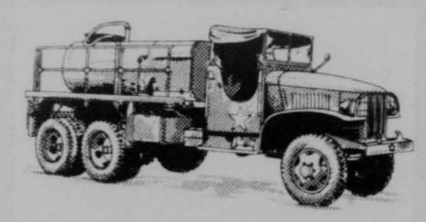
21. DECONTAMINATION PROCEDURES FOR AGENTS

Blister Gases in General

The object is to remove the threat of both liquid and vapor by destroying the gas. Intimate contact beween gas and decontaminant is necessary for rapid decontamination.

Either dry bleach alone or dry mix (two shovelfuls of bleach to three shovelfuls of dry earth) may be used to destroy blister gases. Pure bleach reacts violently with pools of liquid blister gas. Care must be used when decontaminating by this method, since heavy vapor concentrations are exuded.

Wet mix (slurry) is made in two ways: It is a fifty-fifty mixture of bleach and water by weight (for every six shovelfuls of bleach add a 14-quart bucket of water) when used for spreading by brooms or swabs; or it is mixed 40 per cent bleach and 60 per cent water by weight (twenty-six 50-pound cans of bleach



APPARATUS, DECONTAMINATING, POWER-DRIVEN, M3A2 (TRUCK MOUNT)

This apparatus consists essentially of a 400-gallon wooden tank equipped with rotary agitator, 3-cylinder piston-type pump, and relief valve. The truck supplies power to drive the pump and rotary agitator.

Weight of unit empty	11,100 pounds
Water per filling	225 gallons
Filling time from stream	10 minutes
Bleach per filling	1,300 pounds
Filling time with bleach	20 minutes
Mixing time	15 minutes
Average coverage per filling	1,300 square yards
Discharge rate per minute (slurry-1 spray gun)	11 gallons
Discharge rate per minute (slurry-2 spray guns)	20 gallons
Working pressure	400 pounds per square inch

[1,300 pounds] to 225 gallons of water) when used in the 400-gallon decontaminating apparatus. Wet mix should remain on the surface being decontaminated for from six to twenty-four hours, if possible.

Water used by itself hydrolyzes blister gases too slowly for practicable decontamination. It may be used to wash blister gases away mechanically if there is adequate drainage. Special decontaminating personnel with proper equipment may use other means, such as water, soap, and other detergents. (A solution of three pounds of soap shaving and three pounds of washing soda to one hundred gallons of water may be used.) Blister gas sinks to the bottom of pools of water, and care should be taken not to come in contact with the washings.

DANC is an effective decontaminant. It usually is employed in the decontaminating apparatus. The solvent alone (acetylene tetrachloride) may be used to wash away blister gases, but the washings remain dangerous.

Burning the area or object is a quick way of decontaminating, but tactical considerations may prohibit fires in the field.

After decontaminating measures have been completed, any item likely to be handled by personnel must be tested with detector paper or the detector kit to ascertain that decontamination is complete. (It should be remembered that paper detects only liquid agent.) In all decontamination, gas masks and protective clothing should be worn, including impermeable protective gloves, if available.

HN

Water or soap and water are the most practicable agents for field decontamination of the nitrogen mustards. Hot water is more effective than cold water, but both merely wash the gas away mechanically, and adequate drainage is required to protect personnel.

L and Other Arsenicals (MD, PD, ED)

DANC or bleach is best. Water is only partially effective. Since water may leave a vesicant solid if it is used for decontamination, the surface should be treated with a caustic solution, such as washing soda or lye.

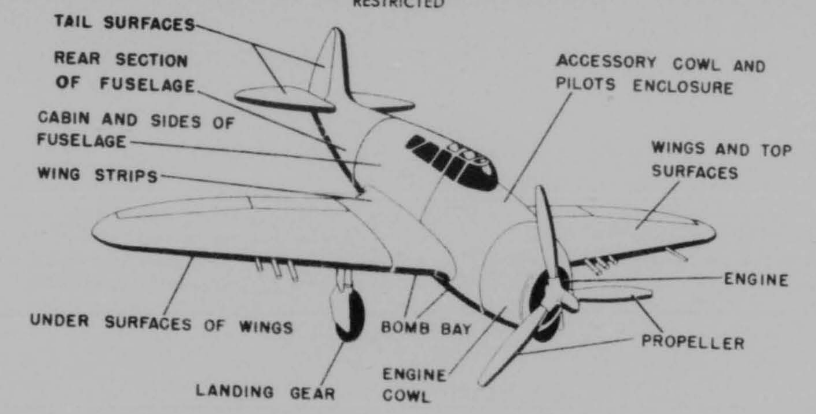
Other Gases

PS and CN, are moderately persistent. PS persists about three hours under average conditions. Aeration is usually sufficient. A hot solution of sodium carbonate (washing soda) neutralizes CN.

22. DECONTAMINATION PROCEDURES FOR MATERIEL

Rubber Articles

DANC should not be used for rubber articles, such as boots and gloves. Several days' aeration in sun and wind suffices if contamination is light. Soaking several hours in water just below the boiling point, or immersion twenty-four hours in a mixture of one part bleach to two parts water (by volume)



SEQUENCE OF AIRPLANE DECONTAMINATION

followed by rinsing and several days' aeration, is better for heavy contamination.

Ammunition

Visible contamination should be wiped with rags. DANC is applied, it is wiped with a gasoline-soaked rag, then dried. If DANC is not available, it should be scrubbed with soap and cool water. If ammunition is corroded, it must be thoroughly cleaned or destroyed. Wet mix (slurry) can be used on contaminated ammunition containers, but it must not be allowed to penetrate to the ammunition itself.

Instruments

If exposed to corrosive gases, instruments should be cleaned as soon as possible with alcohol (or gasoline, if no alcohol is available), and a thin coat of light machine oil applied. A rag dampened with DANC also may be used, followed by drying with a clean rag and application of machine oil. (DANC injures plastic or hard rubber surfaces.) Delicate instruments are decontaminated by special processes by higher echelons.

Weapons

Remove dirt, dust, grease, and oil. Do not apply wet mix, but allow surfaces to aerate after soil and dirt have been removed. DANC can be used on all metal surfaces except the bore. Hot water and soap, or repeated applications with gasoline-soaked swabs, are also effective, and protective ointment can be used for emergency decontamination of small arms as outlined. After decontamination, weapons are dried and oiled.

Airplanes

In flight, the crew of a contaminated airplane must perform sufficient decontamination to continue the mission. Masks and protective clothing should be worn. Vital interior parts, such as seats, instrument board, controls, and firing apparatus, are decontaminated immediately by blotting excess contamination with a rag, then using DANC. It must be remembered, however, that DANC roughens painted and rubber surfaces, and is harmful to plastics. Water is used to decontaminate painted surfaces free from grease and oil, but soap and water may be used more effectively. Bleach paste may be applied to rubber parts. Blister gas sprayed on wings and fuselage loses its vapor danger after flights of one to one and a half hours, but prolonged contact with the contaminated part must be avoided. Masks may be removed after this period, but tests for gas within the interior of the airplane should be made prior to removal. Hot air from the airplane engine heater may be used to decontaminate the interior of the airplane.

Only soap and water should be used on plastic surfaces since protective ointment etches these substances.

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If leaking munitions are the cause of contamination, they should be dropped from the airplane.

Complete decontamination of the airplane is performed by special troops after the airplane has landed.

Automotive Equipment

Light contamination from spray can be decontaminated by aeration alone. For heavier contamination, DANC is used on interior and exterior surfaces which personnel are likely to touch. For larger area decontamination, the vehicle should be washed with water and painted surfaces scrubbed with soap and water. In emergencies when the vehicle is being used, the hood and front parts only are decontaminated. Decontamination of vehicles should begin on the upwind side, upper parts first.

Terrain

Burning the area destroys gross surface contamination (except where there are pools of liquid blister gas) and destroys vegetation holding drops of liquid. Burning does not destroy liquid blister gases which have soaked into the ground; therefore, lying on ground thus treated should be avoided. When burning contaminated areas of grass or brush, great care must be exercised to determine that no friendly troops are within the danger area downwind, and if the area to be burned over is large, additional protective measures must be taken.

Dry bleach, dry mix, or wet mix are satisfactory for decontamination of terrain containing very little vegetation, but these decontaminating agents must be camouflaged either by covering with earth after spreading or by the addition of camouflage materials (dark earth) before using. The amount of bleach to be used is approximately one to two pounds per square yard. Hard road surfaces can be flushed with water under high pressure, or dry bleach can be spread from a bleach spreader. Large flat areas can also be decontaminated by using the bleach spreader to spread dry bleach. Containers of dry bleach may be detonated by use of a suitable explosive to obtain coverage of approximately one square yard of surface per one pound of bleach. Dry mix and wet mix are usually used only for localized areas because of the considerable amount of labor involved.

When decontamination is not practical or necessary, all approaches to the area should be posted with gas warnings, standard or improvised, showing the type of gas and date of contamination or discovery. Signs should be so placed as to give ample warning.

Buildings

Scrubbing with wet mix is the quickest method of decontaminating. Wet mix may be applied from the 400-gallon power-driven apparatus. It is mixed 40 per cent by weight of bleach to 60 per cent by weight of water. (Or 225 gallons of water to twenty-six 50-pound cans of bleach.) This method is especially useful for high vertical surfaces. Wet mix should remain on the surface for six to twenty-four hours before being washed away. Paste may also be used; it is scrubbed into the wood with swabs or brushes. If the surface is smooth, the outside may be washed with water and the washings neutralized with bleach. If the building is not needed, it should be burned or left to decontaminate by aeration after posting suitable warning signs.

Polished and Working Metal Parts

These are decontaminated with DANC. Bleach is extremely corrosive to metals. Kerosene or gasoline may be used to wash liquid blister gas from metal parts, but great care must be used to avoid contact with the washings, since gasoline and kerosene only dissolve and do not destroy blister gas. After decontamination, the parts are washed with soap and water and re-piled. Painted surfaces are repainted, if necessary.

23. DECONTAMINATION PROCEDURE FOR CLOTHING

Removal of Untreated Clothing

If untreated garments have been contaminated even slightly with vesicant they should be removed as soon as the tactical situation

permits. This is true whether the agent is in solid, vapor, or liquid form. A thorough soap bath should follow if at all possible. Serious burns may result if untreated garments contaminated with vesicants are worn even for a few minutes. Even if liquid does not soak through to the skin, vapor burns will result. Should there be a spot of liquid clearly visible upon the clothing, and removing the garment is not feasible, the contaminated portion should be cut from the clothing and protective ointment applied to the body area underneath. Great care should be taken in removing both untreated and protective garments and equipment to prevent contamination of additional skin areas.

Removal of Protective Clothing

A procedure for protective clothing in fixed defenses, which should be followed as closely as possible in the field, is as follows:

A special room, tent, or area is provided with a bench on which to sit. Paper should be placed on the floor at each side of the bench. All men approach the bench from the same side. Wearing their chemically treated cotton gloves, they remove their leggings and shoes. Then they turn and place their feet on the paper at the other side of the bench. Without removing their gloves they take off their hoods, masks, and coveralls. The gloves, underwear, and socks are then removed in that order. All clothing is placed in receptacles provided for this purpose. The men enter an adjacent shower room or field bathing unit and, using plenty of soap, bathe thoroughly. Avoiding the undressing area, they put on clean clothing.

Ventilation

Work upwind, if possible, from a decontamination job or area where large quantities of contaminated garments or equipment are temporarily stored. If indoors, ventilation should be sufficient to prevent accumulation of vapors in toxic concentrations.

Handling of Contaminated Clothing

Items badly contaminated or damaged should be disposed of by burning or burying. Remaining articles should be placed in covered G. I. cans or special gas-resistant sacks for transportation to the quartermaster laundry or to the decontamination site. Handlers should wear gas masks, protective clothing, and impermeable rubber gloves. If the handler is likely to be splashed with contaminated water during the decontamination process, he should wear, if possible, impermeable clothing. At the decontaminating site the containers are opened and the contents sorted into classes, such as wool, silk, cotton and linen, impermeable fabrics, leather, and rubber articles. Each requires a different type of treatment.

Soap and Water

Washing with soap and water is one of the most readily available, certain, and quickest methods of decontaminating all types of individual equipment in the field. Hot soapy water in a can or tub, with a paddle for stirring, insures a cleansing as well as decontaminating action. G. I. or laundry soap is the most satisfactory. Fresh water must be used unless salt water soap is available. Cottons and linens may be washed at much higher temperatures than woolens, which should be washed in a lukewarm soap and water solution to prevent excessive loss of the protecting chemical. Impermeable clothing cannot be laundered. When laundering, the contaminated articles (except woolens) should be stirred in the heated soapy water for at least five minutes. This should be followed by two additional washings and three rinses of five minutes each. If an odor of vesicant remains, the process should be repeated. If it still persists, the items should be discarded and buried or burned.

24. STEAMING

Uses and Duration

Steaming is a suitable decontamination procedure for clothing, fabric, and equipment contaminated with mustard gas. It is not suitable for Lewisite because of the toxic oxide which forms and which cannot be removed by solvents. Garments and textiles exposed to mustard-gas vapor or very small drops should be steamed for two hours at least. If splashed with liquid mustard gas they should be steamed for six to eight hours. Steaming is likely to result in considerable shrinkage of woolens and also produces a small amount of hydrochloric acid which deteriorates cloth. Hot water is generally superior to steaming because an abundance of water dilutes the acid to such an extent that no marked deterioration occurs.

Improvised Apparatus

A steaming unit can be made with a good-sized can, such as a large G. I. can. A false bottom, improvised of pieces of wood or other rigid material, serves to hold the clothing about a foot above the water. Six to eight inches of water are poured into the bottom of the can, the false bottom inserted, and the garments placed on the false bottom. Nails may be driven through the cover of the can and bent to provide hooks for the clothing. This allows the steam to circulate more freely through the contents of the can and insures more intimate contact between the steam and the contaminated clothing. The can should be closed and heat applied. If any odor of vesicant remains in the clothes after steaming, they should be treated again.

25. AIRING

Uses

The simplest but slowest method of decontaminating clothing is by airing it out-of-doors. Garments may be placed, widely spaced, on the ground or bushes, preferably where the sun will strike them and the air will circulate underneath. Clothes should not be placed in such a manner or location that they will attract the attention of the enemy. Airing is suitable for all types of clothing and textiles, but lack of time and unfavorable weather often will prevent its use.

Time Required

Evaporation is hastened by bright sunlight, high temperature, and a gentle breeze. In warm weather at least two days' exposure out-of-doors is necessary for fabrics contaminated by vapors, while four or five days will be sufficient for lightweight garments contaminated with droplets. In cold weather at least two or three days' exposure out-of-doors is necessary for garments contaminated with vapor, while seven to ten days will be required for lightweight garments contaminated with droplets. Heavy garments, other than those of leather and rubber, should be aired two days longer than lightweight articles. To insure complete decontamination of leather and rubber articles, methods of decontamination other than aeration should be employed.

Hot Air Indoors

If facilities permit, contaminated items of most kinds may be hung in a well-ventilated room and subjected to hot air produced by improvised equipment. This method speeds evaporation. Fumes from the room must be delivered to the open air in such a manner that personnel are not endangered. Lightly contaminated clothing may require four to six hours of this treatment if a temperature of about 140° F. is maintained. Temperature should be kept lower than the scorching temperature of the clothing. This method has the advantage of large capacity and no need for water. However, it is not always possible to obtain a suitable room and heating equipment.

26. TACTICAL PROTECTION

Tactical protection includes both active and passive chemical defensive measures taken to defeat enemy chemical warfare action. Maneuver of troops is planned so that gassed areas may be avoided or if avoidance is impossible that they are crossed at points most favorable to the security of the troops involved. Supply movement is planned so that traffic may be routed over alternate routes to avoid contaminated areas. Positions are organized so that alternate positions can be occupied in the event of a gas attack. Alternate positions are selected with a view of counteracting enemy action against the main position as well as affording security against enemy chemical agents released on the primary position. While executing the mission of attacking or defending a position, casualties may be avoided or minimized by the following measures:

Exposing the least number of personnel.

Exposing personnel for the shortest possible time.

Exposing personnel to the lowest possible concentration of war gas.

27. STANDARD OPERATING PROCEDURES

Standing operating procedures (SOP) are orders issued by an air command, air force, wing, group, or squadron, setting forth definite and uniform procedures for chemical defense of the commands. Their adoption tends to eliminate repetition of orders, minimizing danger of confusion and error in combat. SOP's for chemical defense are based on recognized methods of individual and collective protection, and are modified as means and knowledge of protection improve. The various units of a command enforce the SOP and prepare additional plans specifically required for protection of personnel. A guide to the principal items is shown in figure ———.

28. TACTICAL PLANS

General

Tactical plans apply to the local situation. They are carefully coordinated into the general scheme of attack or defense.

Estimate of the Situation

In estimating the situation and drawing up plans, commanders (assisted by chemical officers or unit gas officers) should consider:

The capabilities of enemy weapons and chemical agents.

The weather, terrain, and tactical situation.

Surprise

Generalities have been drawn to show situations which favor enemy use of one kind of chemical agent over another. Favorable weather conditions and a large number of hostile troops are usually considered essential to successful nonpersistent casualty gas attacks. Persistent casualty gas is often used to create or strengthen obstacles, against areas difficult to capture by assault (which the enemy does not intend to occupy immediately), or against marching troops or installations. Surprise, however, should always be guarded against. An enemy may use nonpersistent gas under unfavorable conditions. He may assault a position he has just contaminated with persistent casualty gas. Commanders should be constantly on the alert for signs of an enemy chemical attack, no matter how unfavorable conditions may appear.

29. DISTANT RECONNAISSANCE

Explorations of objectives which lie outside the immediate striking range of a force are conducted by aerial observers and by highly mobile ground forces. Special attention is given areas which normally would be covered in the next several days' operations. Aerial photographs and distant ground observation show location of terrain which, if contaminated, might hamper advancing troops. Enemy chemical activity, such as installations of chemical land mines, may also be revealed. Information may come through raids or by questioning prisoners and inhabitants.

Close Reconnaissance

Chemical reconnaissance becomes more detailed as opposing forces draw together, and particular attention is given to selecting halting points, camp sites, routes of approach, and battle positions favorable or unfavorable to enemy gas attack. Aerial observation and ground reconnaissance help develop information on the enemy's chemical operations, but each unit is responsible for reconnoitering its own front and flanks, routes, and alternate routes of approach. Reconnaissance of gassed areas is difficult at night; accordingly, daytime observation is advocated. But an immediate and quick reconnaissance to determine best means of passage is necessary whenever a gassed area is encountered unexpectedly, day or night. Procedures are as follows:

For areas known to be gassed, the reconnaissance party, suitably protected, examines the area to obtain the following information:

Kind of gas and concentration (heavy, light, medium).

Location and extent of contamination.

Routes for troops and vehicles upwind and downwind of the area, and advisability of masking.

Feasibility of preparing a road, or of using established paths or roads through the area. Part of the group goes upwind to define the edge of the area and explore the possibility of passage there. Other personnel make a similar reconnaissance on the downwind side. Detection devices are used periodically. Occasionally personnel may test for gas by sniffing, but as infrequently as possible. After extent of the area is determined, it is marked with gas-warning signs showing the kind of gas and date of contamination or discovery. Units approaching from the rear are notified. If necessary, sentinels are posted to give warning. Whether passage is made depends on amount of contamination, size of area, availability of routes for bypassing it, terrain and weather conditions, extent of hazard involved, and immediate tactical urgency.

For areas suspected of contamination, careful examination is made, with special attention to low-lying patches of woods, defiles, ravines, stream beds, areas covered with high grass or underbrush, and other spots favorable to contamination with persistent casualty gas.

Battle Reconnaissance

This consists principally of gathering information on the enemy's chemical activities, actual and potential. After a gas attack, battle reconnaissance includes location of gas-free areas and information on which to base recommendations for possible evacuation of contaminated areas.

30. CHEMICAL INTELLIGENCE

After information of military value is collected, it is evaluated by intelligence personnel and disseminated. Only after evaluation does such information become intelligence. Chemical intelligence (like Air Force intelligence in general) may have two main sources: Department of the Air Force (produced under the Department of the Air Force General Staff in peace and in war) and combat (produced in the field by Air Force intelligence sections after the outbreak of hostilities).

Air Force Intelligence

Department of the Air Force intelligence summaries and bulletins are issued for units in the field by higher headquarters. Summaries and bulletins contain information on general chemical warfare developments and on results of research and experimentation. They are furnished to the division chemical officer for distribution to all concerned.

Combat Intelligence

Combat intelligence is based on information gathered by reconnaissance and observation (or by other reliable means) on enemy chemical activity, and is handled through regular intelligence channels. The intelligence itself is furnished to the unit commander by the intelligence officer or his assistants by personal contact, special messages, conferences, periodic reports, or special reports. This intelligence is used by the commander in planning his organization's chemical defense.

Collecting Agencies

Collecting agencies and sources of information available to combat units depend upon the size of the units. In large units, chemical laboratory companies and military intelligence personnel may be included. (The group is the smallest unit provided with intelligence personnel.) Collecting agencies may draw information from such sources as interrogation of prisoners, examination of enemy chemical materiel, or samples of contaminated earth. In smaller units, sources of information are limited to patrols and to unit gas personnel.

Factors Important in Combat Intelligence

The following factors are guides (not limitations) to what is most important in both chemical information and intelligence:

Local weather conditions favorable or unfavorable for enemy chemical attack.

Chemical offensive preparations of the enemy, including his capabilities for using gas, character and amount of his chemical weapons

and ammunition, location and disposition of his chemical troops, and location of weapons and munitions for dispersing gas.

Terrain which is a good target for gas, especially terrain likely to be crossed or occupied by friendly troops.

State of enemy gas training, discipline, and protective equipment.

Data regarding any particular gas attack and official report form.

Data on friendly troops, including friendly use of chemical agents, state of protective equipment, and protection available for food, water, and general supplies.

31. REPORTS

Immediate Reports

These are sent by the unit gas officer, immediately after a gas attack, noting:

Time
Place
Extent of attack
Kind of gas (if known)
Type of weapon used (if known)

32. SELECTION OF ROUTES AND POSITIONS

Factors

In choosing routes and areas, whether original or alternate, the following are particularly applicable to chemical defense:

Elevation. Gas tends to drain to low ground; high ground therefore, is preferable unless contaminated. Air currents in corridors, however, may tend to carry gas up slope and up valley during the day, down slope and down valley during the night.

Concealment and Cover. Woods in leaf offer the advantage of concealment and some measure of cover against spray. Woods with good overhead cover and clear ground beneath are preferable, but concentrations are often higher in woods than in the open.

Freedom from Underbrush. If heavily contaminated, low scrub and long grass may contaminate troops badly. Further, gas vapors linger in heavy undergrowth (particularly if the ground is low), and concentrations may be high there.

Accessibility of Water. (Water supplies are important for decontamination purposes.)

Means of Entrance and Exit. (Paths or roads should be chosen which are not in themselves dangerous from a contamination viewpoint.)

Ample area for dispersion.

Good observation for sentinels.

Other tactical or supply factors. Protection from chemical attack, however, may have to be a compromise with protection from small-arms fire, and from armored or air attack.

Bypassing a Gassed Area

Whenever possible, troops should be moved upwind of a contaminated area. If the situation requires a downwind passage, it is usually safe for masked troops to pass at a distance equal to the depth of the area, but the vapor concentration and weather factors must be considered. Unless the mission demands it, personnel should avoid remaining downwind; troops held there may suffer casualties even if the vapor concentration is low and the contaminated area small. Furthermore, the effects of blister gas are cumulative. If possible, airmen should not be exposed to blister-gas vapors if their skin is red from previous exposure.

Detection of Blister Gas

Troop officers must remember that the odor of mustard gas does not necessarily indicate dangerous amounts of vapor. Harmless impurities (which have an odor similar to the original mustard gas) or reaction byproducts from decontamination may remain in the area after the danger has disappeared. The M9 chemical agent detector kit should be used and the table in the accompanying booklet consulted.

Evacuation of Positions

If a position already occupied is heavily contaminated, casualties may be unavoidable. Tactical considerations may require that such

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a position be held. If the mission can be accomplished by occupation of a previously chosen alternate position, the gassed area may be evacuated and the alternate position occupied. In no case should evacuation of an original position be undertaken until it is clear that the enemy is using blister gas in quantities sufficient to jeopardize the mission of occupying troops. If the position once evacuated is threatened by enemy occupation, it should be reoccupied if it is sufficiently important.

33. OPERATIONS IN GASSED AREAS

Following a suitable lapse of time after gassing, operations can be conducted safely even in areas contaminated with blister gas. Time limits vary, depending upon protective clothing, temperature, type of contaminated soil and terrain, and task to be performed. The M9 chemical agent detector kit should be used and the accompanying booklet consulted to determine approximate time limits after which task can be performed in gassed areas.

On the March

When the mission requires, troops must pass through (or even remain in) contaminated areas. In such cases, operations may be carried on with the minimum number and least severity of casualties if good gas discipline is maintained and all practicable measures of individual and collective security are carried out. In addition, certain techniques are helpful:

Hard surface roads should be used, if available.

If roads are muddy, men should be warned to avoid splashing. Wheels of vehicles, and the feet of both men and animals are cleaned after area has been crossed. Shuffle areas of dry mix should be located at either end of crossing.

Troops should be instructed to avoid visible liquid contamination, whether fresh or old, and especially to avoid contact of liquid with the bare skin.

In motor movements, personnel should be guarded against splashing from branches or from contaminated water and mud on roads.

If the area is dry and dusty, clouds of contaminated dust should be avoided.

Movement should be rapid, reducing time of exposure to vapor. (Troops tire quicker if dressed in protective clothing and masked.)

If tactically possible, contaminated vegetation should be burned along the route, avoiding exposure to concentrated vapors produced by burning.

If practicable, details, dressed in impermeable protective clothing, should be assigned to cut lanes in advance through areas of contaminated ground.

Protection During Pursuit of Enemy

This is achieved by thorough reconnaissance and observance of all other chemical defense measures. The enemy is likely to use blister gas extensively in rear-guard action; therefore, a pursuing force must guard constantly against contaminated ground.

34. LONG-PERIOD OCCUPATION OF CONTAMINATED JUNGLE AREAS

When contaminated areas are limited in extent, troops may be moved to uncontaminated areas for eating, drinking, and personal relief. When the contaminated area is extensive, no gasproof shelters are available, and troops must remain within it for long periods (twenty-four hours or longer), the following procedures are suggested:

Preliminary Reconnaissance

A search should be made for sites likely to become gas-free at the earliest time, and for sites of least liquid contamination. It may be necessary to redispose troops so that they occupy areas free from liquid contamination.

Eating and Drinking

No attempt should be made to remove masks within the first four hours after a heavy mustard gas attack. After this time, tests with the M9 chemical agent detector kit should be made at the sites discovered in the preliminary reconnaissance above.

Urinating and Defecating

A site for a latrine area is chosen in the preliminary reconnaissance, and men must be warned of the necessity for using only the latrine area designated. For urinating, the fly of the protective clothing is unbuttoned to almost its full length with the gloved hand and the fly of the drawers widely exposed. The drawers are then unbuttoned with the bare hand. The genitals should not be exposed for more than one minute. The reverse procedure is followed in rebuttoning the clothing. For defecating, the trousers should be lowered with the gloved hands, and the drawers lowered with the bare hands. The clothes should not touch the ground, and caution must be exercised to avoid touching twigs or grass with the bare skin. The genitals should not be exposed more than two minutes. The reverse procedure is followed when adjusting the clothing.

Sleeping

Sites for sleeping should be chosen during daylight so that areas with liquid contamination can be avoided. A fox hole is dug, or the surface is scraped away even though no contamination is visible. A protective cover (or poncho) is placed under the body but not over it, since blister gas vapor may be trapped. Masks should be worn, and sentinels must see that men do not pull them off while asleep.

35. PROTECTION AGAINST NONPERSISTENT CASUALTY GAS ATTACK

Tactically, the enemy may be expected to assault a given position soon after he lays down a nonpersistent casualty gas attack upon it. Troops must be prepared to repel such assaults. Such preparations should be completed as soon as possible after the gas attack is made. Any unnecessary movement should then cease until the assault is made or until the gas laid down by the enemy has disappeared. Sometimes enemy gas attacks can be forestalled by air or artillery bombardment of the enemy's positions. Even if the gas attack is not forestalled, the enemy's following assault may be stopped by immediate bombardment.

SECTION V—DEFENSE AGAINST INCENDIARY ATTACK

1. STRATEGY AND TACTICS

Incendiary bombs may cause more destruction than any other aerial munition. The incendiary bomb is considered a strategic rather than a tactical weapon, and it has been used mainly against rear area installations, yet its tactical targets include ammunition dumps, advance depots, railheads, airdromes, and supply columns. Incendiary shell, fire bombs, grenades, and flame throwers are primarily tactical.

Type of Attack

Large incendiary bombs customarily are used only on important installations (point targets), such as airdromes, railheads, docks, depots, and factories.

Small incendiary bombs are dropped in clusters against area targets. These bombs disperse in falling, the object being to start a number of separate fires which merge into a major conflagration.

Secondary Missions

Explosive incendiary bombs often are included in incendiary bomb clusters. Besides starting fires, they impede incendiary defense.

Fires started may light the way for high-explosive, precision bombing.

2. ORGANIZATION FOR DEFENSE

Responsibility

Fire defense is a command function and responsibility. The organization for defense against incendiaries is headed by the division engineer, who may be appointed fire marshal. Corps of Engineers fire appliance troops fight appliance fires in a theater of operations. The chemical officer may be designated as adviser to the fire marshal.

Existing Organization

The existing organization for protection against air attack must provide for incendiary defense.

Fire Department Cooperation

A single small incendiary may cause an appliance fire (one which cannot be brought under control by a fire-fighting squad, but must be attacked with professional fire-fighting apparatus). In a theater of operations, large appliance fires are controlled by Army Engineer fire-appliance troops. In the United States, civilian fire-fighting organizations or civilian employees of the Army must fight these larger fires.

General Plans

While no detailed plan will cover all situations, the following are important points in setting up a defense plan:

Fireguard duty is assigned in addition to regular duty. The fireguards are stationed at point targets or important installations and used as patrols in important areas during emergencies.

Additional equipment is improvised.

An inventory is kept of locations of all materials and equipment useful in fighting incendiary bombs. This record should be maintained by the officer responsible for the fire protection of the area.

Fire-fighting supplies and equipment should be kept near all vital centers.

A military area should be divided into sectors, with an officer responsible for the organization and its functioning in each sector.

An air-raid protection organization should be set up.

Training

All personnel should be trained to use available fire-fighting equipment and taught to recognize various types of incendiaries and their characteristics.

Advance Fire-Defense Planning

General. Advance planning and a complete understanding of the plan by all responsible officers are essential. Surveys should be made and a standing operating procedure should be established. Simplicity of plan is of prime importance.

Classification of Areas. As part of the advance planning, areas should be classified according to type of construction, amount of roof coverage, and tactical importance.

3. MEANS OF DEFENSE

Defense against incendiaries must be aggressively conducted.

Precautionary Measures

Inspections should be made to insure the following:

Readily flammable materials must be kept in nonflammable containers.

Waste materials should not be allowed to accumulate.

Wooden surfaces, where practicable, should be coated with white-wash, water-glass solution, or other fire-resistant material (properly camouflaged).

Materials for fighting incendiaries should be readily accessible.

A practical incendiary spotting and alarm system should be in operation.

Combustible supplies should be dispersed.

Ingenuity should be employed in improvising supplementary equipment.

Incendiary Defense Organization

A unit defense organization should be established and taught to use available equipment.

Periodic defense drills should be held. Anti-incendiary discipline of the entire unit should be stressed.

Handling of small incendiaries is a technique that the individual airman can be

METHODS OF COMBATING INCENDIARIES

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taught, just as he is taught the technique of individual gas protection.

A fire guard for first-line defense should be established, consisting of individual fire guards equipped with and trained to use simple fire-extinguishing equipment.

If civilian communities with organized fire-fighting services are near, liaison should be maintained in order to obtain aid for control of fires.

Equipment

General. In the field, incendiaries and the fires that they start must be controlled with equipment on hand for fighting ordinary fires and with improvised equipment. This includes water buckets and barrels, sand and sand bags, garden and fire hose, burlap bags, axes, shovels, flashlights, rope, gas mask or goggles, and gloves. Pump tanks, 3-gallon or 400-gallon decontaminating apparatus, and soda-acid or carbon dioxide extinguishers may also be available. Fire-fighting equipment must be kept in convenient, readily accessible places known to all.

Hose. Prompt flooding with a stream of water from a hose will soon extinguish or control most small incendiary bombs of any type. The high-pressure "fog" nozzle is most effective for oil incendiaries.

Fire Extinguishers. The chief disadvantage of most fire extinguishers is their small capacity. Use of the carbon-tetrachloride extinguisher is not advisable in confined spaces because of the possible generation of toxic fumes. Soda-acid and water types should not be used directly on oil since they tend to spread the fire. The fog nozzle type of extinguisher is effective.

Water Barrels and Buckets. Barrels (kept full of water) and buckets should always be available. In freezing weather, salt should be added to the water in outdoor barrels.

Sand. Even if there is no lack of other equipment, sandbags should be conveniently placed, and containers of dry sand should be available for smothering effect. Twenty-pound sandbags are best for quick and easy handling. Twenty-pound bags, 15 by 12 by 3 inches, are known as "sand mats."

Other Equipment. Pump tanks, knapsack-type pumps, or the 3-gallon decontaminating apparatus are useful when fire or garden hose is not available. Shovels may be used to scoop up bombs or their molten particles for removal to places of safety. The 400-gallon decontaminating apparatus is excellent for fighting fires.

4. METHODS OF COMBATING INCENDIARIES IN IMPORTANT STRUCTURES

General

When an incendiary falls into an important building or area, such as an oil or ammunition depot, an attempt must be made to control the fire in spite of the risk involved.

Precautionary Measures

A percentage of incendiary bombs usually contains high explosives. Unless known to the contrary, all incendiary bombs must be considered to be of explosive type and treated accordingly. Ordinary room walls, tables, chairs, and similar objects do not provide a safe shield for a hose operator fighting such bombs. A brick wall offers adequate protection only against small explosive incendiary bombs. Only one fire fighter should risk exposure in an attempt to extinguish a bomb. When cover is available, the fire fighter's body should be shielded so only the hands are exposed. Helmets should be worn. When cover is not available, fire fighters operate from a nearly prone position and from a distance as great as equipment permits.

Employment of Equipment

Shovels. Shovels can be used to scoop up incendiary bombs after the danger time for explosion has passed. Bombs can then be thrown in a place where no damage will be done.

Sand Mats. Sand mats can be used to smother bombs. Fighters should then take cover, or run twenty yards away and lie flat. This method should be used only when incendiaries are known not to contain explosives. Sandbags or mats reduce fragmentation of

explosive bombs to some degree; some fragments are confined, and those which escape are dispersed over a substantially reduced area.

Loose Sand. Loose sand may be thrown around the bomb, helping to smother fires started by it. Sometimes it may be necessary to cover the bomb with sand and scoop it or the molten particles into a shovel. The bomb or particles are placed in a bucket partially filled with sand. More sand is placed on top, and the bomb is carried to a safe place. This method must not be used for explosive incendiaries.

Water or Fire Extinguishers. Water or fire extinguishers are employed immediately against bombs falling in vital structures, regardless of whether sandbags or sand mats are used. Carbon-tetrachloride extinguishers should not be used in confined places because they may generate toxic fumes. Soda-acid and water extinguishers should not be used directly on oil since they tend to spread the fire. The fog-nozzle extinguisher, however, is effective. Water can be used against other types of incendiaries. It may be projected from a hose, pump tank, knapsack-type pump, or 3-gallon decontaminating apparatus, or small quantities can be thrown from a can or canteen cup. Water serves two purposes—it confines the spread of the fire by wetting down the surrounding area, and it controls the magnesium types of incendiaries by increasing their rate of burning (or it extinguishes them if enough is used). Throwing large quantities of water or projecting a stream on a bomb causes scattering, but also forces the flaming particles away from the fighter.

Decontaminating Apparatus. The 400-gallon decontaminating apparatus can be used in the same manner as regular fire-fighting equipment if trained operators are available.

5. INSPECTION AFTER INCENDIARY ATTACKS

General

After an incendiary attack, maintain a watch for several hours to make certain that fire does not again break out.

Phosphorus or Oil

When phosphorus or oil bombs have been used and the filling is spattered on walls and floors of buildings, the liquid must be kept wet and scraped away with a hoe, scraper, or knife. Then, as the surfaces dry, they must be watched for reignition or remaining incendiary.

Unexploded Bombs

After each incendiary attack, a careful inspection must be made for bombs which have not detonated, and for separated explosive portions which have not detonated.

When such missiles have been located, the spot should be marked with a sign, "Unexploded Bomb," the area roped off, personnel excluded, and the bomb-disposal officer notified. Under no circumstances should untrained personnel handle these unexploded bombs.

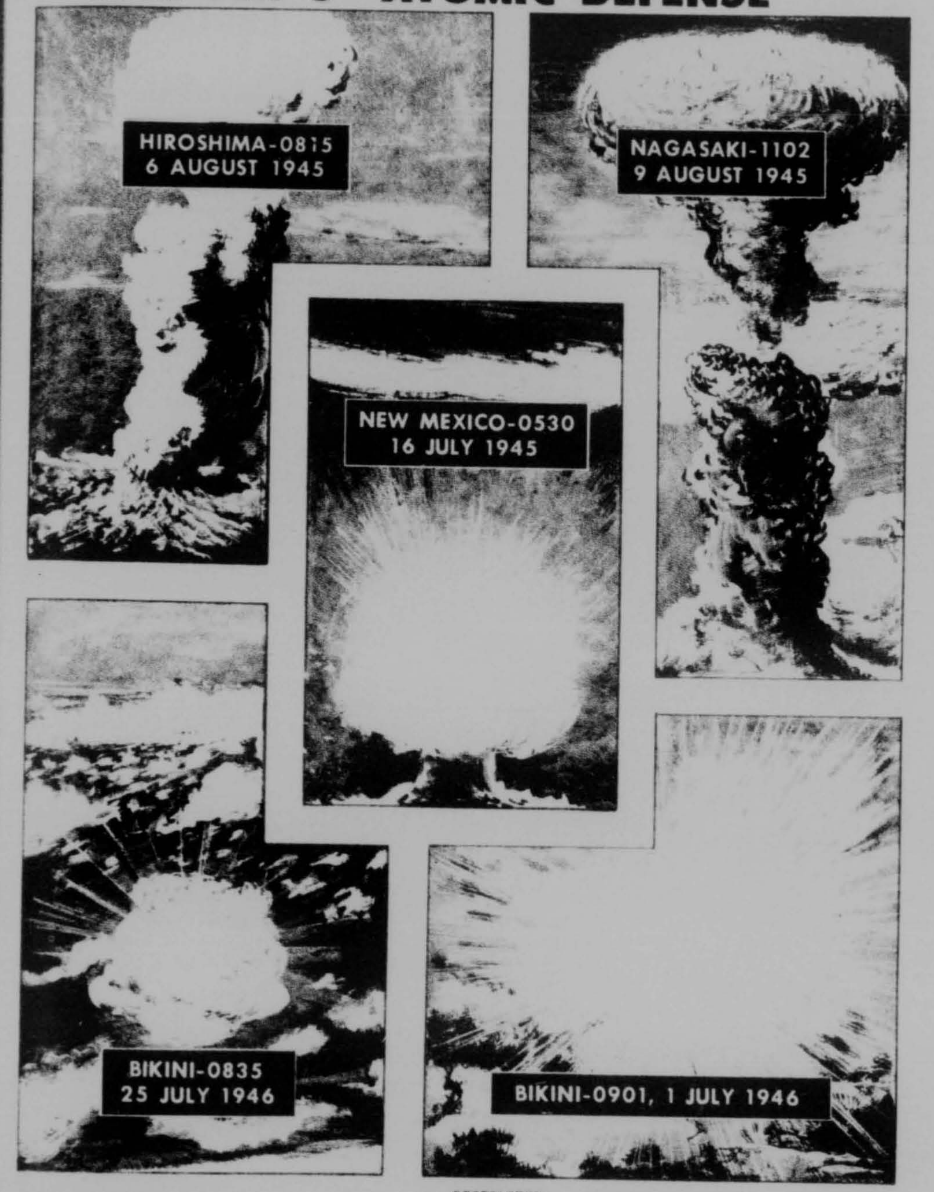
Combustible materials should be removed from the immediate vicinity to prevent their ignition in case the bomb explodes.

Bomb disposal is now a function of the Directorate of Armament. Bomb-disposal crews should be notified through channels.

Equipment

Immediately after a fire has been extinguished, all fire-fighting equipment should be inspected, restored to working condition, and returned to its usual place.

CHAPTER 8—ATOMIC DEFENSE



SECTION I—EFFECTS OF ATOMIC BOMB EXPLOSION

1. INTRODUCTION

The explosion of the first atomic bomb over Hiroshima, on August 5th, 1945, opened a new era in warfare and possibly a new era for all of mankind. Not only was this bomb a powerful new weapon, but it pointed the way to a new source of power for peaceful uses.

The casualties produced at Hiroshima have been variously estimated as being from 60,000 to 100,000. The Japanese figures are higher than those of U.S. military missions which investigated the effects of the bomb. The normal population of this city was about 240,000 but the population had been increased by an influx of the military and war workers. The Japanese estimated that there were about 300,000 persons in the city when the bomb exploded.

It is apparent now that many people died quite unnecessarily. The Japanese had only a skeleton organization for any disaster and under the impact of this blow it broke down completely. A period of five days elapsed before any significant aid reached the stricken city from the outside. Even then, the supply of drugs, blood plasma, and other necessities were not available in sufficient quantities. The medical men often made a faulty diagnosis and prescribed incorrect treatment for the casualties. It is likely that a considerable number of those who died could have been saved if there had been a well-trained and adequately supplied organization to cope with the disaster.

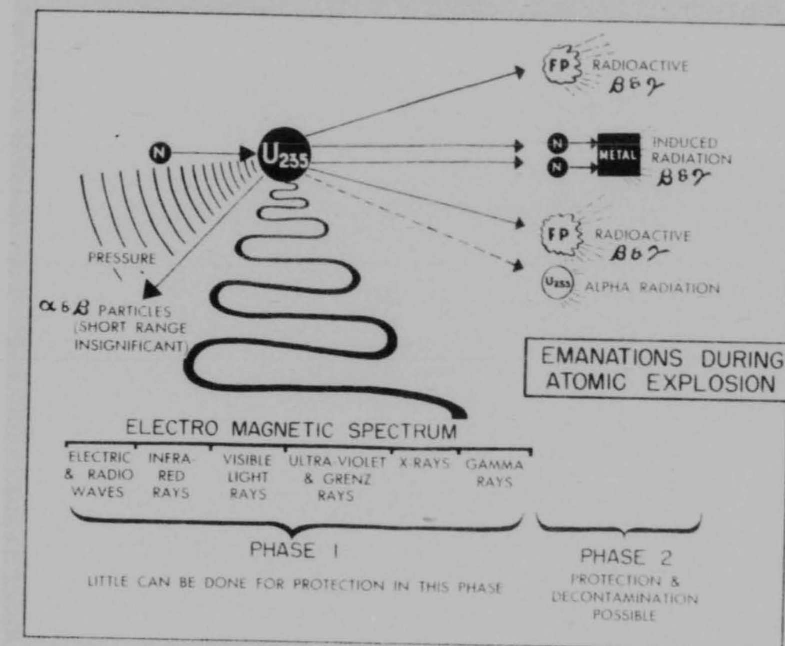
The damage done by the blast effect was enormous; the President announced that it was equivalent to that of 20,000 tons of TNT. Buildings up to a distance of two miles or more from the center of the blast were shattered and four square miles of urban area were destroyed. The destruction blocked streets, imprisoned the wounded in debris and started hundreds of fires. Here again, a well-organized disaster-control group would have been able to save many and to reduce the destruction due to fire outside the wrecked area.

It has been claimed by some that the effect of such an explosion on an American city would be much less severe due to better construction. However, the validity of this argument is questionable. The modern buildings of Hiroshima were built to withstand earthquakes and were of better construction than similar buildings in the average city. It is true that the Japanese homes were of rather flimsy construction, but it is probable that this fact actually saved lives since a casualty was often able to free himself from the wreckage of his home and thus escape the fire which broke out.

When an atomic bomb explodes great quantities of deadly radiations are released. The radiation will be discussed in some detail later in this volume. It is sufficient, for the present, to know that this radiation is deadly up to at least three quarters of a mile from an atom bomb bursting in air; that one type appears at the instant of the bomb's explosion; and that a second type may linger for a long time. Exposure to sufficient quantities of the radiation will kill as surely as bullets will kill. Exposure to high intensities of this radiation may kill quickly or the victim may linger for weeks and then die. The effects of the radiation depend upon the dosage, so that a low concentration for a long period of time may be just as fatal as a high intensity for a much shorter time.

A great amount of heat is developed at the instant of the explosion. In the first few millionths of a second, after the explosion is initiated, a great "ball of fire" develops. This is due to the fact that the gases of the air are heated to a white heat. The temperature, at the center of this mass of hot gas, is millions of degrees centigrade. Once this ball of fire is developed it begins to dissipate by two processes. It rises, rapidly; and it radiates its energy just as the sun, or any other hot body, radiates energy. The energy is radiated as visible, ultra-violet and infra-red light. The visible light can cause temporary blindness, the ultra-violet can cause injuries of the same

UNDERWATER BURST



type as those of sunburn, although much more severe, and the infra-red can kill by producing flash burns. The heat causes combustion in easily inflammable materials up to a mile or more.

The bomb also, at the instant of exploding, emits quantities of gamma radiation. This radiation is the same as that from radium and produces the same harmful effects in the human body. Further, and very important, the explosion scatters certain materials over a wide area and these materials are radioactive and emit alpha, beta and gamma radiation.

Training and Organization Requirements

It seems certain that training and organization are necessary to cope with effects of an atomic blast. This training and organization is not entirely a military matter, for if the nation is to withstand an atomic attack then there must be civilian training and organization comparable in size to the military establishment. It is quite likely that the atom bomb will prove to be a strategic weapon, i.e., it will be used to destroy manufacturing plants, ship yards, ports, and morale rather than being employed primarily against troops. Civilian training is therefore indicated. The training of the military started, on a small scale, in 1947. At the present time there are three joint service schools for military personnel. One is located at the Naval Damage Control Center at Treasure Island, California, and is administered by the Navy. Another is located at the Chemical Corps School, Army Chemical Center, Maryland, and the third is located at Keesler Air Force Base, Keesler Field, Mississippi; these two are administered by the Army and Air Force respectively. The three schools have teaching staffs which are made up of officers of the Air Force, Navy and Army. All three admit officer students of all services and a very few selected civilians.

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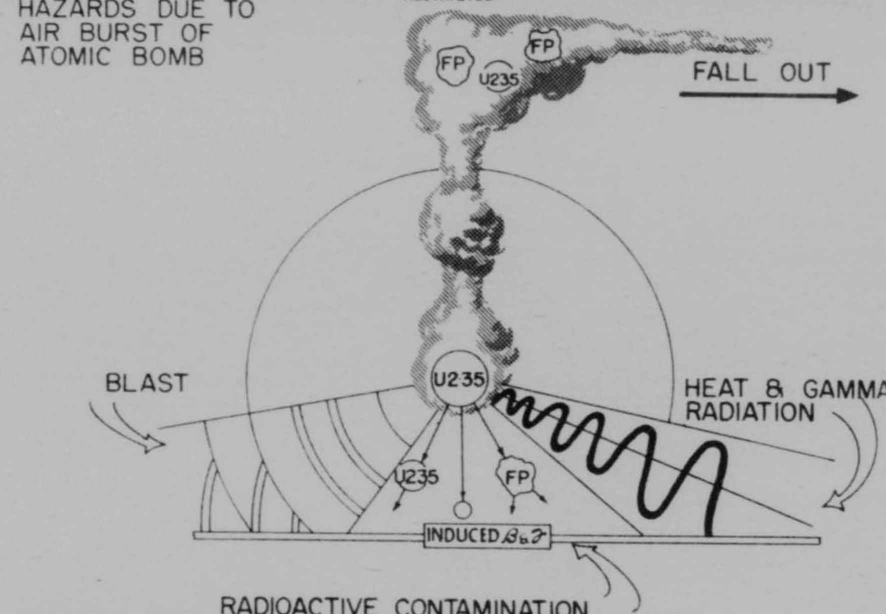

SECTION II—NUCLEAR PHYSICS

1. CHEMICAL AND PHYSICAL REACTIONS

Man has manipulated chemical reactions for many years. The explosion of gunpowder is a chemical reaction. The atomic explosion is not a chemical reaction. It is a physical reaction and it is capable of releasing much more power than can be released by any chemical reaction.

In order to understand the differences between these two types of reactions it is necessary to understand some of the properties of the atom. The atom is a very simple structure. It consists of a nucleus and one or more electrons which revolve about the nucleus in stable orbits. It is in effect a miniature solar system. The nucleus is very small; it has a radius of about ten to twelve centimeters. Almost all of the mass of the atom is in the nucleus since the electrons are very light bodies. The electron moves in an orbit having a radius which is about ten thousand times greater than that of the nucleus. The simplest atom of all is that of hydrogen gas. It has only one electron in an orbit. Helium is the next most complex atom and it has two electrons in its orbits. As the atoms become heavier they have more electrons in their orbits. Thus carbon has six electrons in its orbits and uranium-235 has ninety-two electrons.

Chemical changes, or reactions, do nothing to the atoms involved except change the number of electrons in these orbits.

Physical reactions, which are the basis of the power of the atomic bomb, get their energy from changes in the nucleus. Thus, the Hiroshima bomb was equivalent, as announced by President Truman, to about twenty thousand tons of TNT, yet only a small quantity of fissionable material actually underwent physical decomposition.

Structure of the Atomic Nucleus

Since the physical reaction is the basis of

PERIODIC ARRANGEMENT OF THE ELEMENTS

Series	Period	ZERO GROUP	GROUP I R_2O	GROUP II RO	GROUP III R_2O_3	GROUP IV RH_4 RO_2	GROUP V RH_3 R_2O_5	GROUP VI RH_2 RO_3	GROUP VII RH R_2O_7	GROUP VIII		
0												
1			HYDROGEN H.-1.0078 No. 1									
2	1	HELIUM He.-4.002 No. 2	LITHIUM Li.-6.940 No. 3	BERYLLIUM Be.-9.02 No. 4	BORON B.-10.82 No. 5	CARBON C.-12.00 No. 6	NITROGEN N.-14.008 No. 7	OXYGEN O.-16.000 No. 8	FLUORINE F.-19.00 No. 9			
3	2	NEON Ne.-20.183 No. 10	SODIUM Na.-22.997 No. 11	MAGNESIUM Mg.-24.32 No. 12	ALUMINUM Al.-26.97 No. 13	SILICON Si.-28.06 No. 14	PHOSPHORUS P.-31.02 No. 15	SULFUR S.-32.06 No. 16	CHLORINE Cl.-35.457 No. 17			
4	3	ARGON A.-39.944 No. 18	POTASSIUM K.-39.10 No. 19	CALCIUM Ca.-40.08 No. 20	SCANDIUM Sc.-45.10 No. 21	TITANIUM Ti.-47.90 No. 22	VANADIUM V.-50.95 No. 23	CHROMIUM Cr.-52.01 No. 24	MANGANESE Mn.-54.93 No. 25	IRON Fe.-55.84 No. 26	COBALT Co.-58.94 No. 27	NICKEL Ni.-58.69 No. 28
5			COPPER Cu.-63.57 No. 29	ZINC Zn.-65.38 No. 30	GALLIUM Ga.-69.72 No. 31	GERMANIUM Ge.-72.60 No. 32	ARSENIC As.-74.93 No. 33	SELENIUM Se.-79.2 No. 34	BROMINE Br.-79.916 No. 35			
6	4	KRYPTON Kr.-82.9 No. 36	RUBIDIUM Rb.-85.44 No. 37	STRONTIUM Sr.-87.63 No. 38	YTTRIUM Y.-88.92 No. 39	ZIRCONIUM Zr.-91.22 No. 40	COLUMBIUM Cb.-93.3 No. 41	MOLYBDENUM Mo.-96.0 No. 42	MASURIUM Ma.-? No. 43	RUTHENIUM Ru.-101.7 No. 44	RHODIUM Rh.-102.91 No. 45	PALLADIUM Pd.-106.7 No. 46
7			SILVER Ag.-107.880 No. 47	CADMIUM Cd.-112.41 No. 48	INDIUM In.-114.8 No. 49	TIN SN.-118.70 No. 50	ANTIMONY Sb.-121.76 No. 51	TELLURIUM Te.-127.5 No. 52	IODINE I.-126.932 No. 53			
8	5	XENON Xe.-131.3 No. 54	CAESIUM Cs.-132.81 No. 55	BARIUM Ba.-137.36 No. 56	LANTHANUM La.-138.90 No. 57	CERIUM Ce.-140.13 No. 58						
9												
10	6					HAFNIUM Hf.-178.6 No. 72	TANTALUM Ta.-181.4 No. 73	TUNGSTEN W.-184.0 No. 74	RHENIUM Re.-186.31 No. 75	OSMIUM Os.-190.8 No. 76	IRIDIUM Ir.-193.1 No. 77	PLATINUM Pt.-195.28 No. 78
11			GOLD Au.-197.2 No. 79	MERCURY Hg.-200.61 No. 80	THALLIUM Tl.-204.39 No. 81	LEAD Pb.-207.22 No. 82	BISMUTH Bi.-209.00 No. 83	POLONIUM Po.-209.99 No. 84	ALABAMINE AM.-? No. 85			
12	7	RADON Rn.-222 No. 86	VIRGINIUM Va.-? No. 87	RADIUM Ra.-225.97 No. 88	ACTINIUM Ac.-227.02 No. 89	THORIUM Th.-232.12 No. 90	PROTOACTINIUM Pa.-231.03 No. 91	URANIUM U.-238.14 No. 92	No. 93			

ELEMENTS NOT CLASSIFIED IN THE TABLE ABOVE

PRASEODYMIUM Pr.-140.92 No. 59; NEODYMIUM Nd.-144.27 No. 60; ILLINIUM Il.-146.? No. 61; SAMARIUM Sm.-150.43 No. 62; EUROPIUM Eu.-152.0 No. 63; GADOLINIUM Gd.-157.3 No. 64; TERBIUM Tb.-195.2 No. 65

DYSPROSIUM Dy.-162.46 No. 66; HOLMIUM Ho.-163.5 No. 67; ERBIUM Er.-167.64 No. 68; THULIUM Tm.-169.4 No. 69; YTTERBIUM Yb.-173.5 No. 70; LUTECIUM Lu.-175.0 No. 71

NEW ELEMENTS

NOTE: The following elements have been discovered in conjunction with the work of the Manhattan Project.
NEPTUNIUM, Np, At. No. 93, At. Wt. 239
PLUTONIUM, Pu, At. No. 94, At. Wt. 239
AMERICIUM, Am, At. No. 95
CURIUM, Cm, At. No. 96

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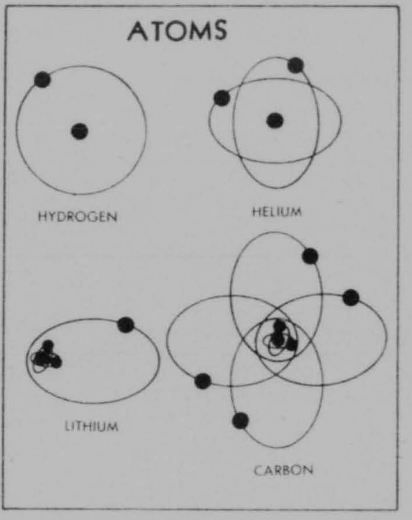
the power which is under study it is necessary to examine the structure of the atomic nucleus with some care. Here also the structure is simple. The nucleus is made up of two kinds of particles packed together. They are known as neutrons and protons. The proton is the nucleus of the hydrogen atom. Its mass is very nearly one mass unit and that value is generally used except for the most precise calculations. The proton carries an electric charge equal to that of the electron but opposite in sign. That is, it carries unit positive charge. The neutron also has a mass of one mass unit, but it carries no charge. Its name comes from the word "neutral".

Discussion of Various Nuclei

It is now possible to explain how the various nuclei of the various types of atoms are built up. Hydrogen is the lightest and simplest atom. Its nucleus is made up of one proton. Helium is the next heavier and next atom in complexity. Its nucleus contains two protons and two neutrons. The mass, or weight, of the helium atom should be equal to four mass units, unless there is some loss of weight due to the energy released by formation (or packing) of the nucleous from the units involved. Lithium is the next more complex atom. Its nucleus contains three protons and four neutrons. Uranium-235 is a heavy and complex atom, but, nevertheless, its nucleus is made up from the same building blocks. The uranium-235 nucleus contains 92 protons and 143 neutrons. Its atomic mass would be 143 mass units for the neutrons plus 92 mass units for the protons, or a total of 235. That is the reason that uranium-235 is designated as it is. In effect, this name means an atom of uranium which has a mass of 235 mass units. There are other uranium atoms. One type, as an example, has a mass of 238 mass units. It is the uranium-235 which is fissionable and which can be used in an atomic bomb. We do not know how to make uranium-238 fission, or explode, therefore we cannot make a bomb of this material.

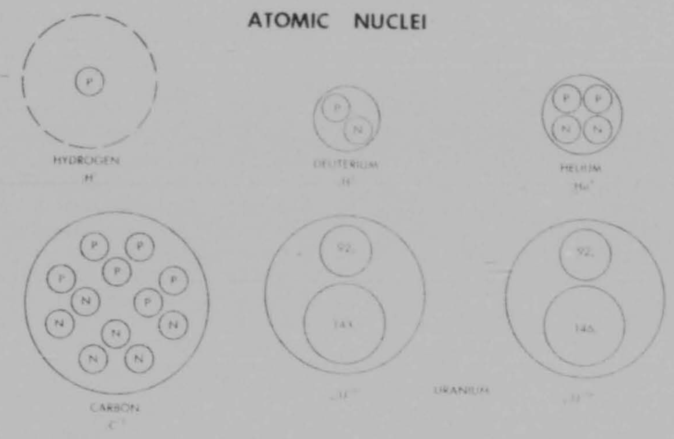
The reason for the number of electrons in the atom's orbits now becomes clear. There are as many electrons in orbits about the nucleus as there are protons in the nucleus.



Helium has two protons in the nucleus and therefore it can attract, and hold, two electrons. Uranium-235 has 92 protons in its nucleus and it can, therefore, attract and hold 92 electrons. It is observed that the uranium-235 atom is surrounded by 92 electrons.

2. ISOTOPES

The word "isotope" is much used today. Isotopes are atoms which have the same chemical properties but different weights, or masses. The chemical properties of any atom depend upon the number of electrons which surround its nucleus. Therefore, atoms with the same chemical properties must have the same number of electrons in their orbits. If they have the same number of electrons, in the orbits, they must have the same number of protons in the nucleus since there is one electron per proton. But, if their masses are different, then the nuclei must have had a different number of neutrons. Thus it is that isotopes, of the same atom, have the same number of protons in the nuclei, but different masses. This difference in mass means very little, in terms of the chemical reaction, but it is extremely important from the view of the physical reaction.



Examples of Isotopes

As an example of isotopes the metal caesium may be considered. This is a soft gray metal, much used in photo-electric cells. It has twelve known isotopes, ranging in value from 133 mass units to 145, inclusive, with no isotopes of mass 134 mass units observed. Of the twelve isotopes of caesium which are now known only one, that of mass 133 mass units, is found in nature. All the others are radioactive and are manufactured in the atomic piles or are a by product of an atomic explosion. These radioactive isotopes decay, or lose their radioactivity, by emitting radiation which is harmful to living matter. Thus, after an atomic explosion radioactive caesium would be scattered in the vicinity and as it decayed it would emit harmful radiations.

The Uranium Isotope

Uranium has seven known isotopes. Three of these occur in nature. These have masses of 234, 235 and 238 mass units. It is the 235 isotope of uranium which has been used in an atomic bomb. We do not know, at this time, how to set off a chain reaction, which leads to an atomic explosion, in the other two isotopes.

Radioactive Isotopes

It has been mentioned that the radioactive isotopes decay by the emission of energetic radiations. Certain naturally occurring radioactive isotopes have been known for many years. Radium is an example that is well-known. Radium decays by the emission of alpha and beta particles and gamma photons. The alpha particle is the nucleus of the helium atom; i. e., it is a particle which consists of two neutrons and two protons. The beta particle is nothing but a high-speed electron. The gamma photons are particles of electromagnetic radiation. That is, they have the same general character as do x-rays, or radio waves. The photon has no electrical charge. The alpha particle, since it is the nucleus of a helium atom, has a double positive charge and the beta particle has a negative charge of one unit. (Figure 8-1). The particles which are of

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ATOMIC BUILDING UNITS			
Unit	**Symbol**	**Mass**	**Charge**
PROTON	p	1.007589	+
ELECTRON	e, β^-	0.000542	−
NEUTRON	n	1.00895	0
POSITRON	e^+, β^+	0.000542	+
DEUTERON	d	2.014726	+
ALPHA PARTICLE	α	4.003842	2^+
THE MASS OF THE HYDROGEN ATOM IS 1.007589+0.000542=1.00813			

Figure 8—1. Atomic Number Z.

particular interest to this group are:

Particle	Symbol	Mass
Proton	H^1, or p	1 mass unit
Beta Particle	B^1- or -e	1/1840 mass units
Alpha Particle	$_2He^4$	4 mass units
Neutron	$_0n^1$	1 mass unit

Particle	Charge
Proton	+1
Beta Particle	—1
Alpha Particle	+2
Neutron	

Other Radioactive Substances

The decay of natural radioactive radium has been discussed. There are several known naturally occurring radioactive substances. One of these is actinium. Actinium decays by the emission of an aplha particle. This gives a new isotope, or atom, which has a mass of four units less and a nucleus which has two less unit charges. This is so because the alpha particle, which is emitted from the actinium atom's nucleus has a mass of four units and has two protons. Thus, by this process the actinium atom becomes an atom of protactinium. The electron has a very small mass and, therefore, the new atom has very nearly the same mass as did the parent but it has one more charge in the nucleus. This is so because by the act of discharging an electron the nucleus changed a neutron into a proton.

The decay process continues in this fashion. Alpha particles, or beta particles, are omitted and the parent atom changes, or decays, to become a new, or daughter, atom. At times, gamma photons are also emitted, and, significantly, all of those radiations are harmful to man. Also, it is important to note that this process continues until the initial radioactive atom decays, by a series of such steps, and becomes a stable atom. The actinium atom decays until it becomes an atom of lead (Figure 8-2).

It must be kept in mind that the material which an atomic bomb scatters is also radioactive. This material also decays by the emission of alpha and beta particles and gamma photons to become, eventually, a stable material, but, the radiations emitted in the process are harmful, they may even be deadly if they are present in sufficient quantities. Some of these decay processes go forward rapidly and one would not expect the radiation due to their decay to be present for a long period of time. However, some of them decay slowly and once an atomic bomb has been exploded, on or below the surface in an area, it must be expected that radioactivity will be present for many years. One of the radioactive isotopes of caesium has a half-life of thirty-three years. Thus, if a certain number of these atoms were scattered about in an area only one half of them would decay in the first thirty-three years. Some radioactive materials actually have half-lives of millions of years.

Source of Energy of Emitted Particles

It has been stated that the atomic explosion will scatter many radioactive atoms about and that these atoms will decay by the emission of harmful radiations. However, nothing has been said as to the source of the energy of these emitted particles. It comes from the nucleus. The nucleus loses some of its mass in the process and gains energy. This means that a new concept must be accepted. This is, "mass and energy are equivalent." This means that mass may be converted into energy. Thus, the nucleus decays and in so doing changes a small amount of its mass into energy and the energy is carried off by the radiation.

This concept of the equivalence of mass and energy is actually not new at all. It comes out of Einstein's relativity theory and was

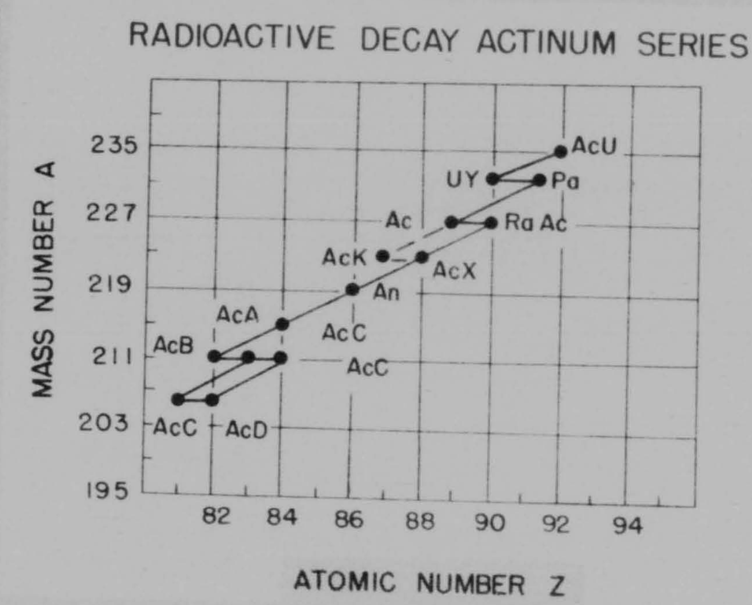


Figure 8—2. Fission, Followed by Decay of Radioactive Isotopes.

stated by him in 1905. His statement is, $E=mc^2$. This short equation merely states that if m grams of matter are converted into energy they give mc^2 ergs of energy. However c is the velocity of light and is equal to $3x10^{10}$ centimeters per second and therefore c^2 is equal to $9x10^{20}$. Thus, the conversion of a very small amount of mass releases a great deal of energy. Assume that in an atomic explosion only one gram of matter is converted into energy. Also, assume that the explosion takes place in one-millionth of a second. Then during that short time, $1x10^{17}$ horse power are developed. This is considerable power on any scale of values.

The notation commonly used to designate these isotopes should be mentioned. Consider the expression $_2He^4$. This is the designation of the helium atom, or isotope. The He stands for helium. The subscript $_2$ refers to the nuclear charge, or the number of protons in the nucleus. The superscript 4 refers to the mass which is four units in this case. Thus, the three isotopes of uranium, which occur in nature, are written as $_{92}U^{234}$, $_{92}U^{235}$ and $_{92}U^{238}$. Note that these are all uranium, that is they have similar chemical properties and the same number of protons in the nucleus, but they have different masses, and while their chemical properties and the same number of protons in the nucleus, but they have different masses, and while their chemical properties are exactly similar their physical properties are quite different. This is shown by the fact that only the U^{235} can be made to fission by chain reaction methods.

Fission

The term "fission" has been mentioned several times. This term is used to describe the process by which an atom of uranium-235 or plutonium divides into two or more parts having a total weight somewhat below that of the parent substance with the release of energy equivalent to the weight of matter which has disappeared. It is the process which is used in the bomb and which may some day yield a new source of power. The heavy uranium, or plutonium, atom undergoes fission, or splits, into two new atoms which are much lighter and which are atoms of other materials. About 200 million electron volts of energy is given up for each atom which undergoes fission. This energy comes, again, from mass. The mass of the original atom is greater than the sum of the masses of the two atoms which are left after the fission process.

The fission reaction is caused by a neutron. That is, a neutron enters the nucleus of a uranium atom and the atom blows up. This reaction does not always occur in the same way, that is, the uranium nucleus can split in a number of ways, it does not split into the same two atoms each time. Some two hundred different isotopes have been identified as being formed by this fission process, but, for the purposes of this class, all that need be remembered is that the process is started by a neutron, it yields a great amount of energy and the two atoms which are left, after the splitting, are almost always radioactive and decay to stable substances by the emission of harmful radiations. At the instant of the fission the atom also throws out two or three additional neutrons, some gamma photons and beta particles.

Therefore, since the fission reaction is produced by a neutron and since the reaction throws out neutrons, if one atom can be made to fission it might in turn set off one or more atoms and thus the process should grow. It actually grows to explosive proportions within a fraction of a millionth of a second. This is the manner in which an atomic explosion takes place. (Figure 8-3).

When the atomic bomb is detonated a great

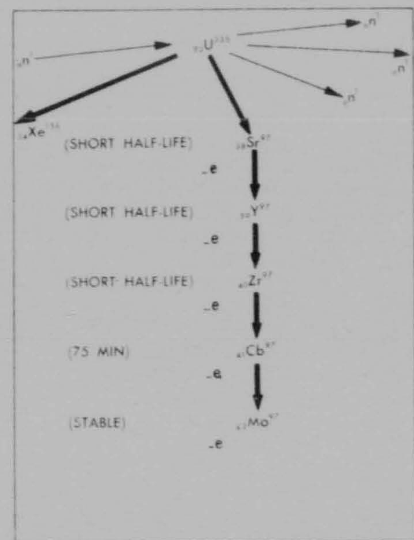
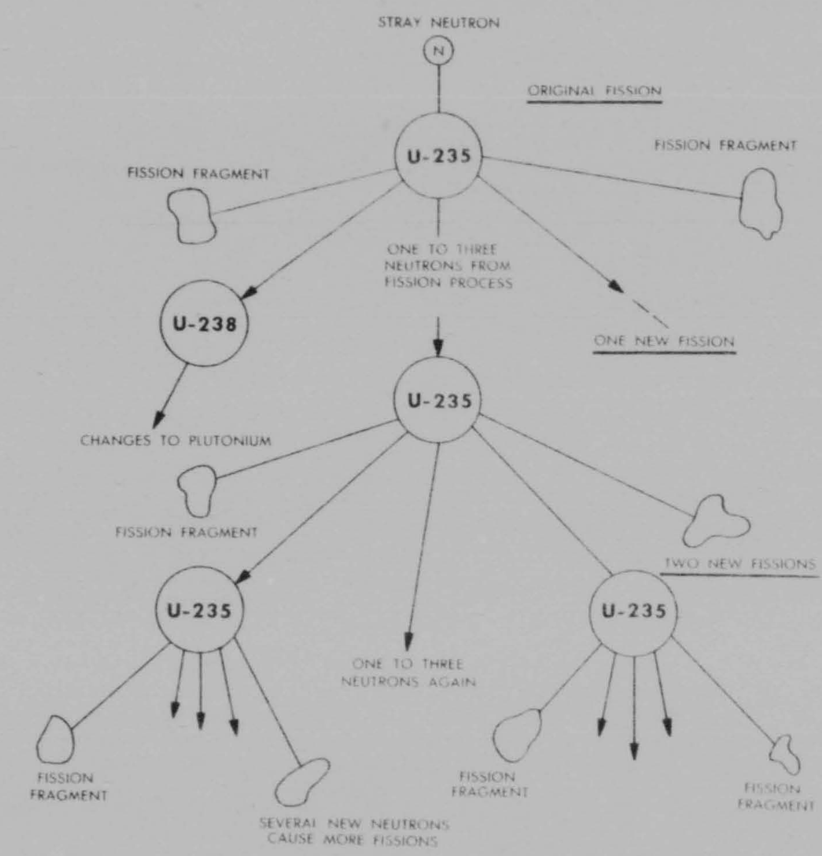


Figure 8—3. Comparison of HE and Atomic Explosions.

amount of energy is released within a very short period of time. This energy produces high temperatures and a great shock wave, but it does more than this. It produces intense infra-red and ultra-violet radiation; it produces a heavy flux of neutrons which can be deadly to the individual who is too close to the explosion; it produces great amounts of gamma radiation which can be deadly for individuals even though they are indoors and some distance removed from the explosion, but all of this is only a part of the story. The explosion scatters radioactive materials over wide areas. These materials decay and this decay process yields radiation which is also harmful. It is seen that the atomic bomb has many characteristics of the TNT bomb but it also has hazards far beyond anything produced by the TNT explosion.

SECTION III—ATOMIC EXPLOSION PHENOMENA



A DIAGRAM OF CHAIN REACTION IN U-235 (FAST FISSION)

Figure 8—9. The 263-Portable Beta and Gamma Geiger-Mueller Counter.

1. CHARACTERISTICS

The characteristics of the HE explosion are well known. The TNT explosion is a chemical reaction. A chain reaction, which proceeds with great velocity, is set up in the body of the explosive. This reaction converts a small volume of solid material into great quantities of heated gases. Due to the temperature and the pressure of the generated gas, a shock wave is set up in the air, for the air burst, or in the ground and the air if the explosion takes place in contact with the earth. The energy expended in this manner is quite large, per unit mass of the explosive, but it is trivial compared with the energy

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developed by the fission of the same amount of uranium or plutonium.

The shock wave which is set up in the air by an explosion, whether it be due to TNT or to an atomic explosion, moves outward from the center of the explosion with a velocity which is generally greater than the speed of sound. This wave is a compression wave in the air. The normal air pressure is about fifteen pounds per square inch. In the shock wave there are two conditions. There is a region in which the air pressure is greater, by several pounds per square inch, than the normal pressure. There is a second region in which the pressure is lower, by a pound or so, than the normal. These two regions constitute the shock wave. The greater the intensity of the explosion the greater the increase in the positive part of the pressure pulse and the less the pressure in the negative pulse. Also, the greater the intensity of the explosion the greater the velocity with which the shock wave moves outward from the point of the explosion. (Figure 8-4.)

Shock Waves

Assume that instruments for the measure of air pressure are set up at some distance from the point at which several pounds of TNT are to be exploded. The explosion develops the shock wave which moves outward and crosses the position of the recording instruments. The instruments will record an increase in pressure which is followed immediately by a decrease in pressure. It is this shock wave which blows out windows and often causes the collapse of structures. The positive phase of the shock wave lasts for about one-millionth of a second and this is followed by the negative pulse which lasts for about three-millionths of a second. Thus, the shock wave, for the TNT explosion, comes as a sharp blow, or pulse of pressure increase followed by a decrease in pressure. As the shock wave travels outward its intensity constantly falls off and the velocity with which it moves also decreases.

The atomic explosion also produces a shock wave which has the same general characteristics as does the TNT wave. Since the atomic explosion is more intense it would be expected

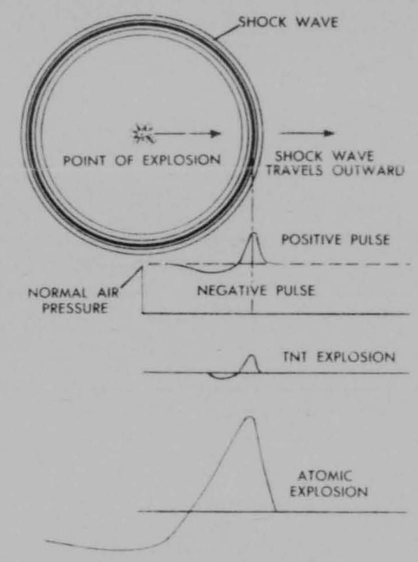

Figure 8–4. Model 247A–Dec. 1947.

that the shock wave, which accompanies it, should show a higher pressure in the positive pulse and a lower pressure in the negative pulse. Also the shock wave should travel at a higher rate of speed for the atomic explosion. This is exactly what is observed. The positive pulse may show increases in pressure which are several times the increase for the TNT explosion. The duration of the pulse may be as great as one-tenth of a second. This is 100,000 times the duration of the pulse due to a TNT explosion. It is to be noticed that if the positive pulse increases the normal air pressure, by, for example, five pounds per square inch, the shock wave can be very destructive. There are 144 square inches to the square foot and if a positive pulse of this amount impinged upon the wall of a building it would mean that each square foot of surface of the building, on the side facing the explosion, would be subjected to a force of 144 x 5—720 pounds. Further, this pressure would persist for about one-tenth of a second. Assume that a small building, eight feet high and ten feet long stands facing the point at which an atomic explosion takes place. The

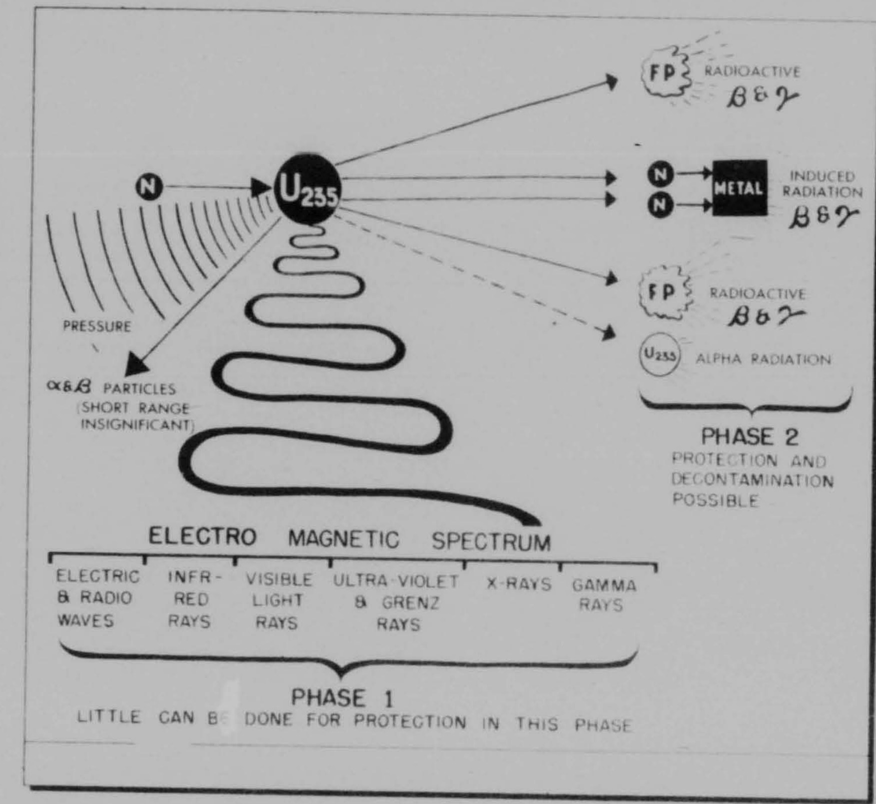

Figure 8–5. The 263–A Portable Beta and Gamma Geiger-Mueller Counter.

total force against this side of the building, due to the shock wave, would be (8 x 10) x 720 or about 29 tons. It is easy to see why most buildings will not withstand the shock wave due to an atomic explosion if they are located near the point of the blast. Thus, at Hiroshima, multistoried brick buildings were severely damaged if they were within a radius of one mile from the point of the explosion. Even modern reinforced concrete buildings were severely damaged if they were within a radius of two thousand feet from the point of the explosion.

To this point nothing new has been mentioned concerning the effects of atomic explosions. That is, the shock wave developes for this type of explosion about as it does for the TNT explosion. It is true that the shock wave is more intense; that is, the positive pulse rises to a greater value and it lasts for a much longer period of time. The shock wave of the atomic bomb is therefore much more destructive. But the mechanism by which the shock wave is developed is the same as for the TNT explosion.

Radiation Effects

As has been mentioned earlier, the atomic explosion is accompanied by radiation effects which are entirely missing from the

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TNT explosion. The effects of these radiations can be very serious and they will be discussed here. The radiation effects can be divided into two parts. The first group consists of those radiations which accompany the actual explosion of the bomb, the second group is comprised of those which linger, or persist, after the explosion. The radiation which accompanies the explosion can be classified as follows: (Figure 8-5.)

Electromagnetic radiation
Neutron flux
Beta particle radiation
Alpha radiation

The electromagnetic radiation can further be subdivided into ultra-violet, infra-red and gamma radiation. The ultra-violet is the same ultra-violet radiation which is found in sunlight. It has the same effect upon the skin; that is, it produces a sunburn. This burn can be severe enough to kill. Any lightweight shielding material is sufficient to protect against the ultra-violet radiation.

The infra-red radiation is heat radiation. That is, it is the infra-red portion of the sun's spectrum which transmits most of the heat. This radiation is very intense in an atomic explosion. It can set fires at considerable distances. It will produce flash burns on exposed skin tissue at considerable distances from the explosion. However, shielding will give considerable protection against it. Also, it was found at Hiroshima that individuals who were exposed to the infra-red and who were wearing light-colored clothing escaped flash burns while those who wore dark clothing received severe burns. It was also noticed that loosely fitted clothing gave more protection than did tight clothing.

The gamma radiation has the same general characteristics as does x-ray radiation. However, it is more energetic and it will penetrate greater thicknesses of shielding materials. It was estimated that, at the instant of the Able explosion at Bikini, the gamma radiation was equivalent to that of several hundred tons of radium. Since all of the world supply of radium is measured in pounds this is truly an astronomical figure. Lightweight shielding affords no protection. Gamma radiation is not completely stopped by any amount of shielding. All that the shielding does is to reduce the intensity of the radiation. Thus if the shielding is heavy enough and the source of the radiation is not too intense the individual does not receive enough radiation to cause serious effects. It was estimated that, at Hiroshima, twenty-four inches of concrete would have been sufficient to protect an individual at a distance of one mile from the explosion. For nearer points, the thickness of concrete would have to be greater. Five inches of compact clay will reduce the intensity of the gamma radiation by about one-half, but the intensity is so great that the intensity must be reduced by nearly 100 per cent if the individual is to escape injury. It is to be noticed that if five inches of clay reduces the intensity by 50 per cent, then ten inches will reduce the intensity by 75 per cent and fifteen inches will reduce the intensity by 87.5 per cent. In general the heavier materials are the more efficient in reducing the intensity of gamma radiation. Thus, less thickness of lead shielding would be required than would be the case for paper or wood. The walls of a house, of wooden construction, would afford excellent protection against the ultra-violet and infra-red radiation and almost none against the gamma radiation.

The neutron has been mentioned in an earlier lecture. It was also mentioned that the neutron causes the fission of uranium and plutonium and that neutrons are ejected from nuclei when they undergo fission. These fission neutrons are high energy neutrons and they can penetrate great thicknesses of matter. Thus, at Bikini, neutrons penetrated the steel bulkheads of ships and induced radioactivity in table salt and soap chips in the galleys. The neutron itself can cause harmful effects in the human body, but it also acts in another way. It can induce radioactivity in many substances. Thus at Bikini, and especially in the Baker test, the neutrons from the explosion caused the formation of a radioactive salt from the normal salt in the sea water. This radioactive salt then decayed, and in the process, emitted a great deal of gamma radiation. Thus, the neutron flux, which was generated at the instant of the explosion, gave rise to a lingering type of radioactivity.

Beta particles are emitted at the instant of the explosion, but they are not a serious

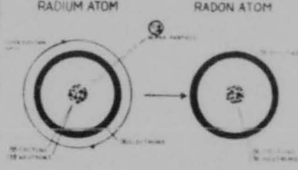
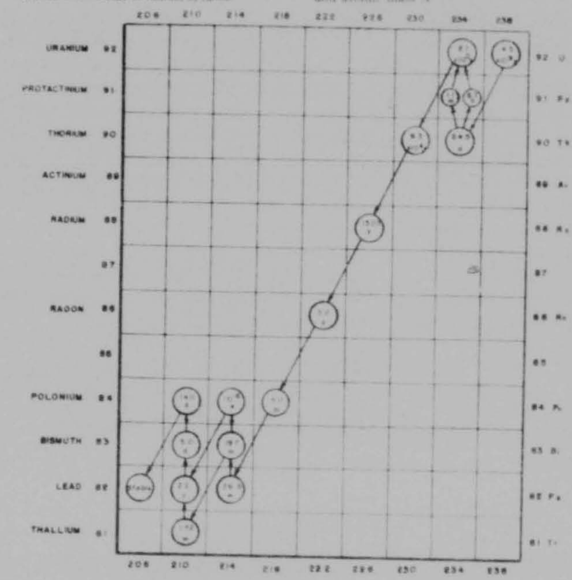


Figure 6-5.—Decay of radium to radon

$$_{88}Ra^{226} \longrightarrow {}_{86}Rn^{222} + {}_{2}He^{4} + Q \qquad (7)$$

Just as in chemical equations, there has to be some type of a balance made on both sides of the equation. It will be noted that the superscripts representing the atomic masses add up to the same total on each side of the equation, as do the subscripts which represent the atomic numbers of the isotopes. In fact the equation for natural α-emission can be written in a more general form which applies to any element of atomic number Z and atomic mass A.



RADIOLOGICAL SAFETY

threat. The beta particle is a charged particle and will, therefore, have a short range in air. The energetic beta particles from an atomic explosion will have ranges of only about ten meters in air. Thus, while they are harmful, their range is so short that they need not be seriously considered.

Alpha particles also arise in the explosion. They are heavy compared with the beta particle, therefore their ranges are measured in centimeters. If an alpha emitter becomes lodged in the body it can be a very serious hazard, but it is not serious as long as it is external to the body.

This concludes the list of harmful radiations which arise at the instant of the explosion. They are, gamma radiation, ultra-violet and infra-red radiations, neutrons flux, beta particle radiation.

The radiation which arises at the instant of the explosion is not the only harmful radiation. There are types of radiations which persists after the explosion. This radiation arises from three sources. These are:

Unfissioned bomb material.

Fission produces of the bomb material.

Radioactivity induced in the materials of the land or sea.

Unfissioned Material

All of the material of a bomb does not undergo fission. This unfissioned material, either uranium-235 or plutonium, is reduced to a powder and scattered by the explosion. This material is an alpha particle emitter. It is not much of a hazard, due to the short range of alpha particles in air, unless it is taken into the body through the mouth or through open cuts. It then becomes a really dangerous hazard. This effect will be discussed later in this volume.

A part of the bomb material undergoes fission. It has been pointed out that, in the fission process, the atoms of uranium or plutonium break up to form lighter atoms and that these newly-formed atoms are radioactive. They decay by the emission of beta particles and gamma radiation. The beta particles are not a particularly dangerous hazard since they, like, the alpha particles, do not have a great range in air. The gamma radiation however is very dangerous. The gamma radiation from these radioactive atoms can be dangerous up to a thousand or so yards and since the fission products will also be widely scattered by the explosion the gamma radiation may be dangerous over a large area after an explosion.

The hazard due to induced radioactivity can be great in some types of explosions. This hazard is produced by the neutrons which are released at the instant of the explosion. These neutrons enter the nuclei of some atoms and cause a physical reaction which leaves a radioactive atom as a product. Not much is known about the induced radioactivity for the atomic explosion over land. However, the Bikini test showed that for underwater bursts great amounts of radioactivity are induced. This is due to the fact that the salt in the sea takes up neutrons to form a radioactive form of salt. This radioactive salt decays by emitting gamma and beta radiation and becomes magnesium. Considerable gamma radiation, due to this reaction, was present after the Baker test at Bikini.

SECTION IV—BIOLOGICAL EFFECTS OF BLAST AND RADIATIONS

1. CHARACTERISTICS

The primary and secondary radiations produced by an atomic explosion have been discussed previously. The radiations are conveniently divided into two classes. The first class consists of those radiations which arise at the instant of the explosion. They may be further broken down into two types. These are the electromagnetic and particle radiations. The complete list of these is as follows:

ELECTROMAGNETIC RADIATION
- Visible light
- Ultra-violet light
- Infra-red light
- Gamma radiation

PARTICLE RADIATION
- Alpha particles
- Beta particles
- Neutrons

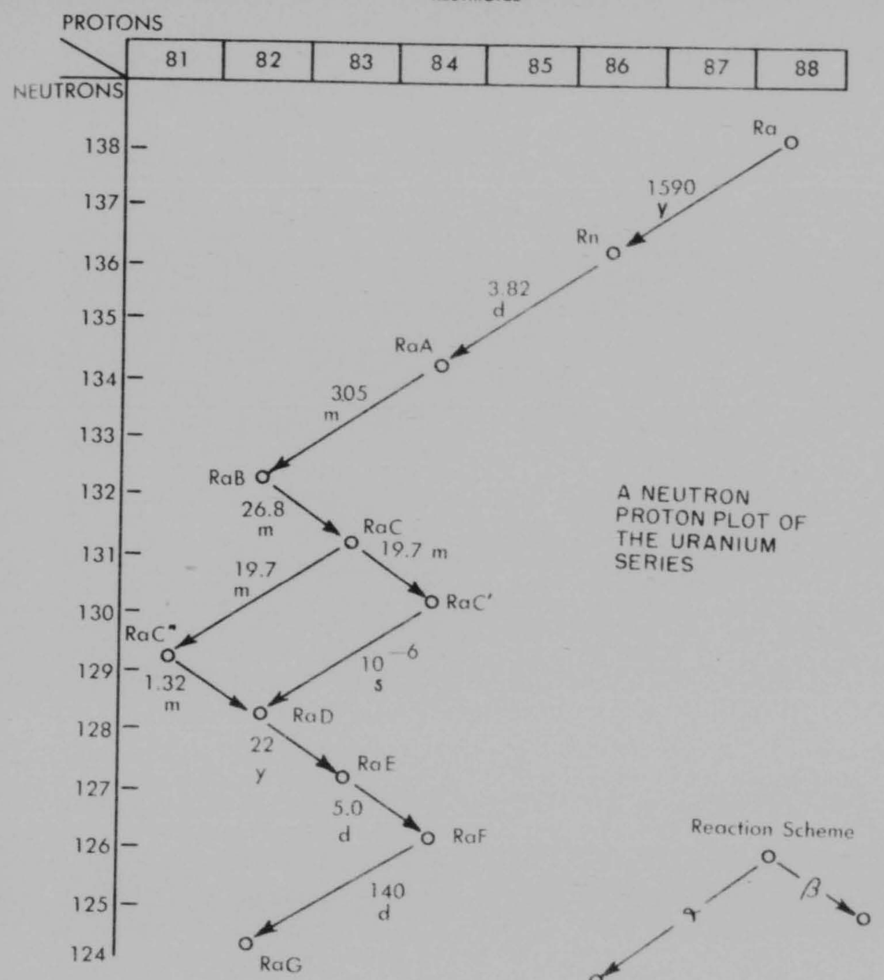
In addition to these radiations the explosion sets up a shock wave which is very destructive. This effect is generally referred to as the "blast effect." The effect of all af these radiations and of the blast effects will be briefly considered.

Primary and Secondary Casualties

The casualties produced by an explosion are often classified as being due to primary or secondary explosion effects. Thus casualties produced by the gamma radiation or directly by the shock wave would be primarily casualties while those produced by flying debris, falling buildings or fires would be secondary casualties.

Hazards

The hazards, to individuals, due to the



atomic explosion are as follows:

Visible Light. The temperature of the ball of fire which is developed at the time of the explosion is very high. Therefore, it is very bright. This brightness produces flash blindness, which, however, is temporary. No cases of permanent eye injury have been reported.

Ultra-violet. It has been mentioned that the bomb produces ultra-violet light and that this is the same type of ultra-violet that is found in sunlight. In general, the shorter the wave length of the ultra-violet light the more harmful it is to the human body. Fortunately, the most harmful portion of the sun's ultraviolet radiation is filtered out by the earth's atmosphere and does not reach the surface of the earth. This is not true for the atomic explosion. This type of radiation will, therefore, produce burns much like those produced by

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The Uranium Series

Element	Symbols	Half-life	Particle emitted: Type	Particle emitted: Range or energy
Uranium	$_{92}U^{238}$ (UI)	4.4×10^{9} years	α	2.67 cm.
Thorium	$_{90}Th^{234}$ (UX_1)	24.5 days	β^-	0.13 Mev.
Protactinium	$_{91}Pa^{234}$ (UX_2)	1.14 minutes	β^-	2.32 Mev.
			γ	0.80 Mev.
Uranium	$_{92}U^{234}$ (UII)	3.4×10^{5} years	α	3.23 cm.
Thorium (Ionium)	$_{90}Th^{230}$ (Io)	8.3×10^{4} years	α	3.2 cm.
Radium	$_{88}Ra^{226}$	1,590 years	α	3.39 cm.
			γ	0.19 Mev.
Radon	$_{86}Rn^{222}$	3.825 days	α	4.08 cm.
Polonium	$_{84}Po^{218}$ (RaA)	3.05 minutes	α	4.69 cm.
Lead	$_{82}Pb^{214}$ (RaB)	26.8 minutes	β^-	0.65 Mev.
			γ	
Bismuth	$_{83}Bi^{214}$ (RaC)	19.7 minutes	α	4.1 cm.
			β^-	3.15 Mev.
			γ	1.8 Mev.
Polonium	$_{84}Po^{214}$ (RaC')	10^{-6} seconds	α	6.95 cm.
Thallium	$_{81}Tl^{210}$ (RaC'')	1.32 minutes	β^-	1.80 Mev.
Lead	$_{82}Pb^{210}$ (RaD)	22 years	β^-	0.0255 Mev.
			γ	0.047 Mev.
Bismuth	$_{83}Bi^{210}$ (RaE)	5.0 days	β^-	1.17 Mev.
			γ	
Polonium	$_{84}Po^{210}$ (RaF)	140 days	α	3.87 cm.
Lead	$_{82}Pb^{206}$ (RaG)	Stable		

TABLE II.—*Naturally radioactive light elements*

Element	Isotope	Half-life	Type of emitter
Potassium	$_{19}K^{40}$	1.42×10^{9} years	β, γ
Rubidium	$_{37}Rb^{87}$	6.3×10^{10} years	β
Samarium	$_{62}Sm^{148}$	1.4×10^{11} years	α
Lutecium	$_{71}Lu^{176}$	7.3×10^{10} years	β

rate at which it is produced but also of the rate at which it decays. In considering this case, the problem is relatively simple, since the decay rate of radium is so slow that the number of radium atoms present at any time can be considered constant. Let

N_1 = the number of ra... t

N_2 = the number of radon atoms present at time t

Then

$\lambda_1 N_1$ = the number of radon atoms formed per second by decay,

where

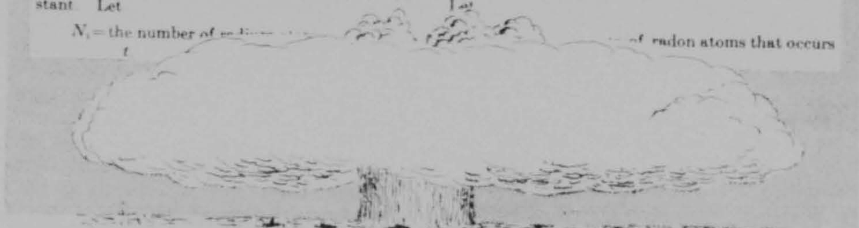
λ_1 = decay constant of radium.

Then

$\lambda_2 N_2$ = the number of radon atoms decaying per second.

Let

... of radon atoms that occurs



too long exposure to strong sunlight. It is to be noted that any light material will give adequate protection against the ultra-violet light. Thus, even the protection afforded by a suit of light colored clothing saved many of the Hiroshima citizens. The walls of the ordinary home were ample protection against the ultra-violet radiation.

Infrared: The infrared radiation carries off, by radiation, most of the heat developed by the bomb. It has been estimated that from 20 to 30 per cent of the Hiroshima casualties were due to flash burns and it must be assumed that the infrared radiation was most efficient in producing these burns. It has been estimated that the skin of many of the casualties was heated to a temperature as high as 2,000°C even though the individaual may have been as much as 2,000 feet from the blast. Clothing was set afire even though the wearer was as much as 6,000 feet from the point of detonation of the bomb. Telegraph poles were scorched up to distances of 10,000 feet.

However, the infrared, like the ultra-violet, has no penetrating power and any lightweight shielding gives protection. The reflections should be of some light color since a light color reflects most of the heat energy and does not absorb it. Thus, individuals who were dressed in light-colored clothing often escaped flash burns while others, close by, who were dresed in dark clothing received severe burns. The most protection was offered by clothing which was light in color, which fitted loosely and which consisted of several layers.

Gamma Radiation. The gamma radiation which is released at the instant of the explosion is very penetrating and is, therefore, very difficult to shield against. It is estimated that, for the Hiroshima explosion, from 15 to 20 per cent of the casualties were due to this type of radiation. The walls of the average building afford almost no protection. The clinical effects of exposure to either x-rays or gamma radiation are described by the general term of "radiation sickness." Some of the manifestations of radiation sickness are:

a) Loss of hair. Incidence of this type of injury was 75 per cent at 500 yards from the explosion. The loss appears about two weeks after the explosion. This loss does not appear to be permanent.

b) Mouth and gastro-intestinal tract. Nausea and vomiting shortly after exposure is followed by lesions of the mucous membranes of the mouth due to the radiation. A bloody diarrhea appears within a few days of the explosion.

c) Effects upon the reproductive organs. In the male, radiation produces sterility. In many cases this is temporary but it must be assumed that exposure to high intensity radiation will probably produce sterility for a long period of time. No complete report of the production of sterility in males exposed to the Hiroshima or Nagasaki blasts has been made up to this time (early 1948). To date there is no record of permanent sterility.

The female reproductive organs appear to be more easily injured than the male. It was noted that, at Hiroshima, miscarriages seemed to be more frequent after the explosion. There are no data on the frequency of premature births after the explosion.

d) Effects upon the blood forming system. Gamma radiation can easily penetrate the body and reach the bone marrow. The blood forming organs are susceptible and may be injured. This leads to leukemia or a white blood cell deficiency. This makes the individual susceptible to infection. The injury to the blood-forming organs also leads to anemia or deficiency of red blood cells. Anemia produces loss of skin color and a general weakness. Gamma radiation, by means of the injury to the blood-forming organs, also produces a tendency towards bleeding. This is due to deficiency of platelets in the blood stream. Thus, severe hemorrhages occur even though the injury may be minor. Hemorrhages may occur spontaneously.

It is to be noticed that the effects upon the blood-forming system can be serious secondary effects. The individual who has been injured by the blast, or by secondary blast effects such as flying debris, may later die due to secondary infection. The general treatment which is indicated, for radiation sickness, is: scrupulous sterile techniques, transfusions, use of penicillin, leukocytic cream and folic

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acid A, careful study and nursing care. It should be mentioned, in passing that the victims of the Hiroshima bombing did not receive such care and that proper care would have materially reduced the deaths due to exposure to gamma radiation.

e) Alpha Particles. The alpha particles which arise in the explosion have fairly high energies. However the alpha particle has a short range, a few centimeters, in air and does not constitute an external hazard. That is, if an alpha particle emitter enters the body it will probably reach the bone marrow. Thus the emitted alpha particles, even though their range is short, can injure the blood forming organs. The substances which emit alpha particles behave, therefore, much like radium. All of the material of the bomb does not undergo fission. The unfissioned material is pulverized by the blast and scattered over a large area. Personnel in an area contaminated with these materials must not smoke, eat or drink. Every precaution against stirring up clouds of dust must be observed.

f) Beta Particles. The range of the energetic beta particle is measured in a few meters. Therefore, the beta particles which arise in the explosion do not constitute much of a hazard. No beta particle radiation is particularly dangerous as an external hazard. However, the fission products (that is the material which undergoes fission) are beta emitters and they, like the unfissioned material, are widely scattered by the explosion and they constitute a real internal hazard. The means of protecting the individual against the internal hazards of beta particles are the same as those mentioned for protection against the internal alpha particle hazard.

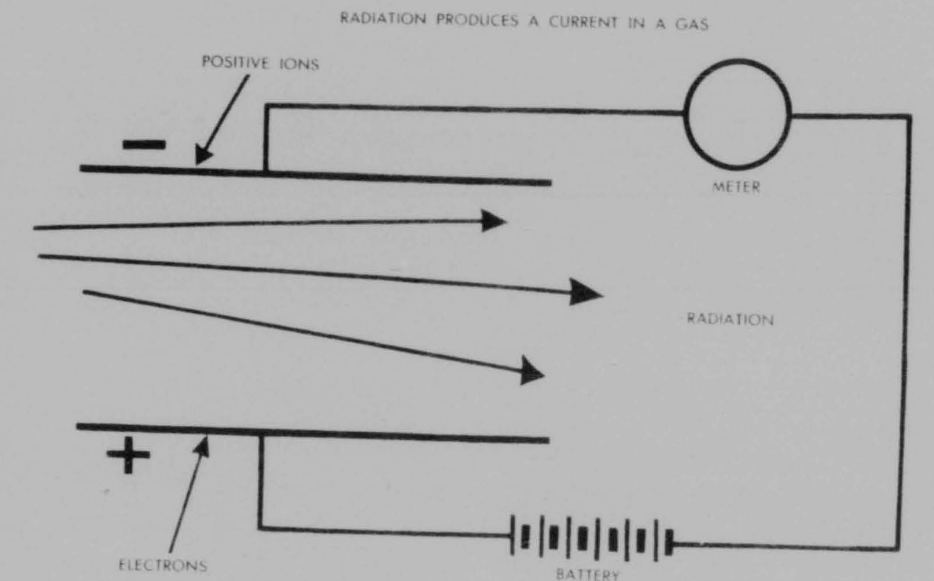
g) Neutrons. The neutron, like the beta and alpha particles, is a heavy particle. Unlike the alpha and beta particle the neutron has considerable range in air and in dense materials. It has been mentioned that the neutrons which were generated in the Able explosion at Bikini penetrated the hulls of ships in the lagoon. The effects of the neutron upon the human system are not well-known. However, it appears that fewer neutrons can produce more hazardous effects than would be the case for gamma photons. The neutron owes its power to penetrate considerable thicknesses of materials to the fact that it has no electrical charge. Thus, low energy neutrons can penetrate the body and even though they are low energy particles they can produce harmful effects. They do this by destroying the reproductive cells.

There is another way in which the neutron produces harmful effects. The neutron reacts with many substances. The products of such reactions are almost always radioactive and decay by the emission of beta particles and gamma radiation. Thus, at Bikini, the underwater burst gave large amounts of radioactive salt. This salt was produced by the reaction of the neutrons which were set free at the instant of the explosion with the normal salt of the sea water. It is not known how efficient the neutrons would be in producing radioactivity in the materials of the land when the bomb is detonated under the surface or close to the surface.

The effects described to this point are radiation effects. This does not mean that the blast effects were not important. In both the Hiroshima and Nagasaki explosions, more than half of the casualties were produced by the blast effects, primary and secondary.

The casualties due to primary blast effects were few. That is, even though the shock wave was tremendously destructive of buildings, it directly caused but few casualties. Most of the casualties, due to blast effects, were secondary in nature. Individuals were injured by falling buildings, flying debris and fires which were caused by the collapse of buildings and from heat radiations which started fires in easily combustible substances within a mile of the explosion center.

SECTION V—RADIATION DETECTION INSTRUMENT



1. DESCRIPTION AND OPERATION

Radiation is measured in various units, only one of which will be mentioned here. This unit is the roentgen. It is defined in terms of certain physical constants and the exact definition will not be given. All that need be known here is that the medico-legal standard, in this country, prescribes that more than one-tenth roentgen per day constitutes a radiation hazard. There is no time element in this definition. That is, the one-tenth roentgen may be received in one hour or twenty-four hours. It is assumed that there is no hazard as long as no more than one-tenth roentgen of radiation is received by the individual within any twenty-four hour period.

Principles of Operation

Radiation detecting instruments, at the present time, are based upon two principles. The first is the fact that harmful radiation will ionize gases. The second type of detecting device is based upon the fact that gamma, alpha and beta radiations will all cause a blackening of a film. The first type of instrument will be discussed in some detail and the second type, since the underlying principle is rather widely known, only briefly.

A neutral gas shows no electrical charge. That is, the gas in a room is made up of countless numbers of molecules of oxygen, nitrogen and some other molecules. Almost all of these molecules are usually neutral. However, in the presence of radiation the molecules become charged and if an electric field is applied to a body of the gas, a current will flow. Such currents are known as ionization currents and are weak.

Radiation ionizes a gas by tearing away one or more of the orbital electrons from the gas atoms, or molecules. This leaves a free electron and a positively charged molecule.

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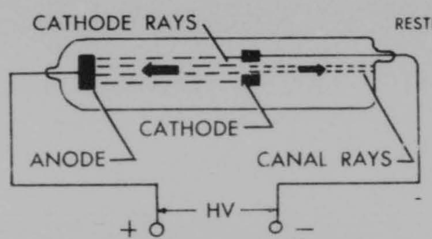


Figure 8–6. Canal Rays Passing Through a Hole in the Cathode of a Cathode Ray Tube.

The charged molecule is generally referred to as an ion. In the presence of an electric field the ions move to the negatively-charged pole and the electrons to the pole with the positive charge. Thus, the presence of radiation can be detected by the very weak current which flows through the battery which supplies the potential to the charged poles, or plates. These currents are so weak that elaborate electronic amplifying devices must be used. However, in this brief discussion the amplifiers will be ignored and it will be assumed that meters of infinite sensitivity are available. (Figure 8-6).

Types of Instruments

There are two commonly used portable types of detecting instruments which depend upon the ionization of a gas by the radiation. These are the ionization chamber instrument and the Geiger-Mueller (or G-M) type instruments. The ionization chamber instrument is commonly referred to as the 247-type radiation detector while the G-M detector is referred to as the 263-type instrument.

The ionization chamber consists of a chamber about three inches long and two inches in diameter which is fitted with a probe which extends down the center of the chamber. The probe is insulated from the chamber and carries a positive potential of 100 volts or so. When radiation enters the chamber, ions are formed and move to the probe and the chamber wall. This causes a current to flow in the external, or battery circuit, and the amount of current is a measure of the intensity of the ionization. (Figure 8-7).

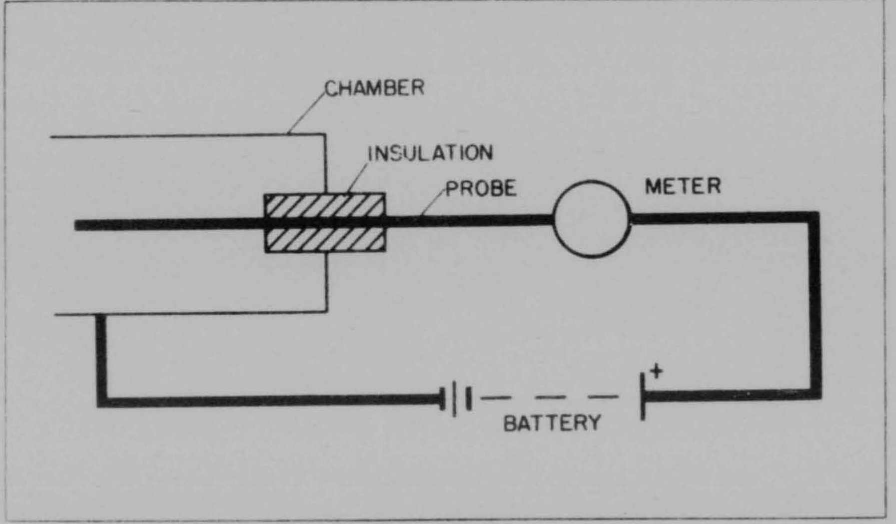


Figure 8–7. Ionization Chamber.

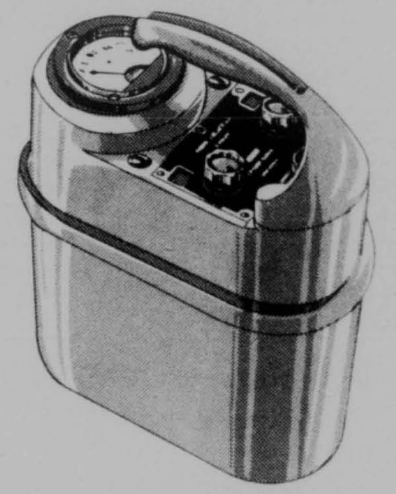
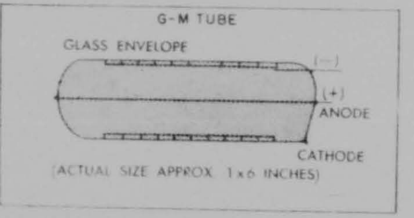


Figure 8–8. The 247 Meter.

The ionization chamber, of the type used in field work, is rugged and will measure high intensities of radiation. However, it has certain disadvantages. The 247 meter is heavy but it will not measure low intensities of radiation; that is, it has low sensitivity. Other meters are light but still have the same low sensitivity. (Figure 8-8).

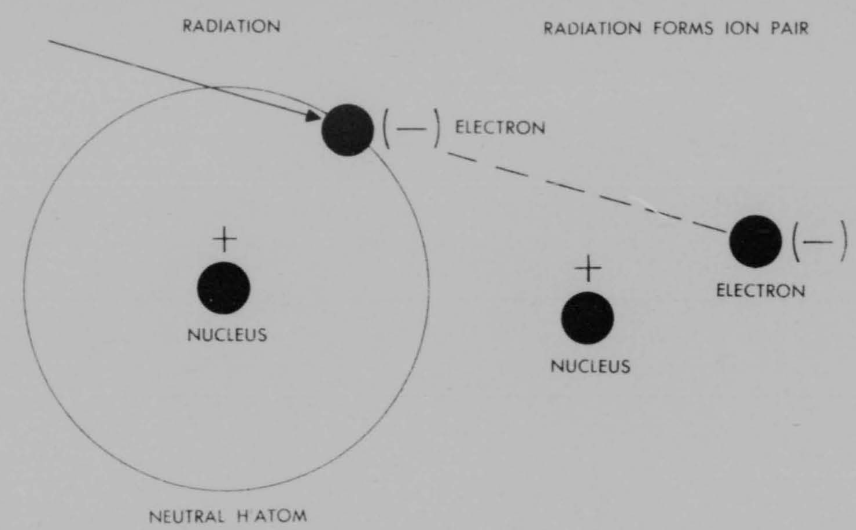
The G-M type instrument uses a G-M tube as a detector. This tube is normally constructed of glass. It is about six inches long and one inch in diameter. The glass tube is carefully cleaned of air and then filled, to a pressure of about one-fifth atmospheric, with argon, neon or helium. The gas is deliberately contaminated with a trace of other gas and also with a trace of a heavy organic vapor such as the vapor of one of the alcohols. Inside the glass tube a very lightweight cylinder of metal is fitted against the tube wall. This constitutes the cathode. A wire of very small diameter runs the length of the tube. This wire is so connected to the battery that it carries a positive charge. Thus it constitutes the anode. Radiation, which penetrates the



tube, forms free electrons and ions and these migrate to the anode and cathode respectively. The G-M tube, in the field-type instrument, will not detect alpha particles since the alpha particle does not have sufficient energy to penetrate the glass wall of the tube. (Figure 8-7).

To this point in the discussion it appears that the G-M detector behaves much like the ionization chamber. However, there are great differences. In the ionization chamber there is no gas amplification. That is, the electrons and ions which are formed by the radiation, are collected in the chamber. In the G-M tube, due to lower gas pressure and high applied potentials, there is gas amplification. This means that in the G-M type tube the electrons, which are formed by the original radiation, succeed in forming more electrons. Thus, in a good G-M tube a single electron which might be knocked from an orbit of an atom, may be amplified by the gas and a million electrons might be collected at the anode. It is obvious that the greater the amplification in the body of the gas, the less amplification that will be necessary in the auxiliary electronic amplifier.

Since the G-M detector requires less auxiliary amplification, the 263A type instrument is lighter than the 247 type. Also, the 263 instrument will measure much weaker radiation intensities that can be detected by the 247. However, the 263 instrument has certain disadvantages. It will not measure high intensities of radiation. The G-M tubes wear out rather rapidly. This is due to the loss of the organic vapor in the tube. Also, in order that they may detect low energy beta particles, the G-M tubes are constructed with a very thin glass window and are therefore easily broken. (Figure 8-9).



Neither of these detection instruments is satisfactory for field use. This was amply demonstrated in the Bikini tests. They are too delicate, their battery requirements are too high and they are far too costly. A great deal of work is now being done on instruments which operate upon different principles and it is quite likely, that within a year or two, instruments will be designed which are much more satisfactory for field use by military personnel.

Both the 263- and 247-type instruments measure the radiation intensity at a point and at an instant of time. Neither will furnish any indication of the **total** amount of radiation to which an individual has been exposed **during** a period of time. It is often necessary to know this. Thus, if an individual were to board one of the radioactive ships after Bikini he would want to know how much radiation he had been exposed to during his stay aboard. If the total amount exceeds one-tenth roentgen, for one day, he has received too much. If the excess were not too large he would be kept out of radiation for a day or so and then allowed to reenter the hot zone. If the excess were quite large he would be placed in a hospital for observation and if necessary, treatment.

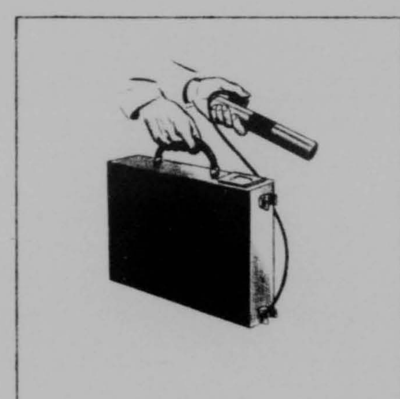
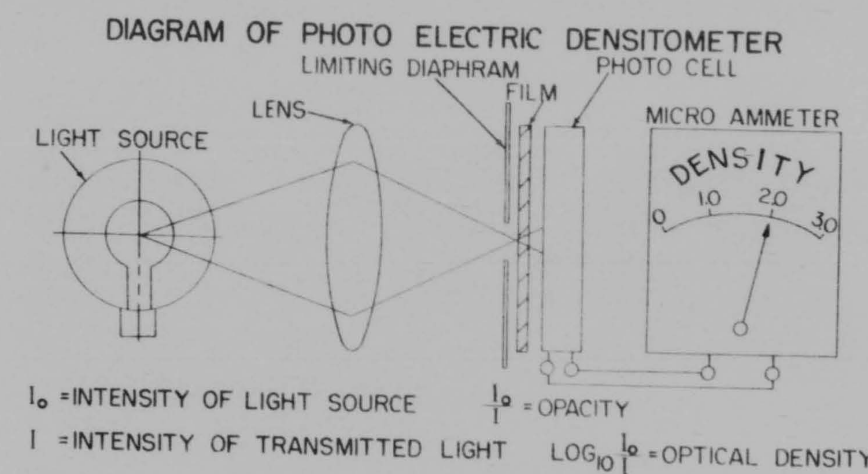


Figure 8—9. The 263-Portable Beta and Gamma Geiger-Mueller Counter.

2. TOTAL-RADIATION MEASURING INSTRUMENTS

There are instruments which will measure the total radiation during a period of time. This is commonly referred to as the dose or dosage and the instruments which measure it



are known as "dosimeters" or dose measuring instruments.

Dosimeter

A common type of dosimeter is made up in the form of an oversized fountain pen. It consists of a metal cylinder which supports a wire probe. The probe runs the length of the cylinder and is supported upon electrical insulators. Thus, the outer cylinder is the case and supports the wire probe and its insulators.

This dosimeter is used in conjunction with another instrument which is called a "minometer." At the beginning of a period the dosimeter is inserted in the minometer and a positive charge is placed upon the central probe of the dosimeter. Then, as radiation passes through the cylinder the electrons formed travel to the probe and neutralize the charge. Thus the amount of charge which is neutralized, in any period, is a measure of the total amount of radiation which passed through the dosimeter during the period from the time it was charged until the remaining charge was measured. The remaining charge is determined by again inserting the dosimeter in the minometer and reading the deflection of an instrument which is built into the minometer (Figures 8-10A, B, C).

A dosimeter is now being used for those devices which are direct reading. Charging boxes used with these so-called "minometers" are used to charge and read pocket chambers.

The dosimeter, therefore, gives an indication of the radiation dose which an individual receives during any period of time. It's small and may be carried in the pocket as a fountain pen is carried. They have been used by work-

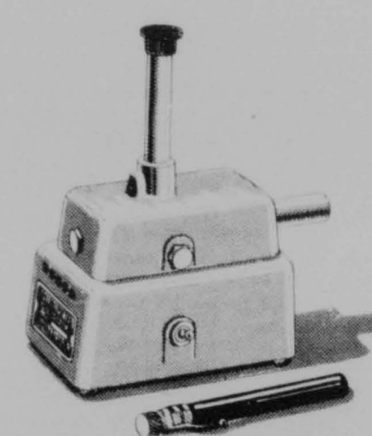


Figure 8—10 A- Minometer.

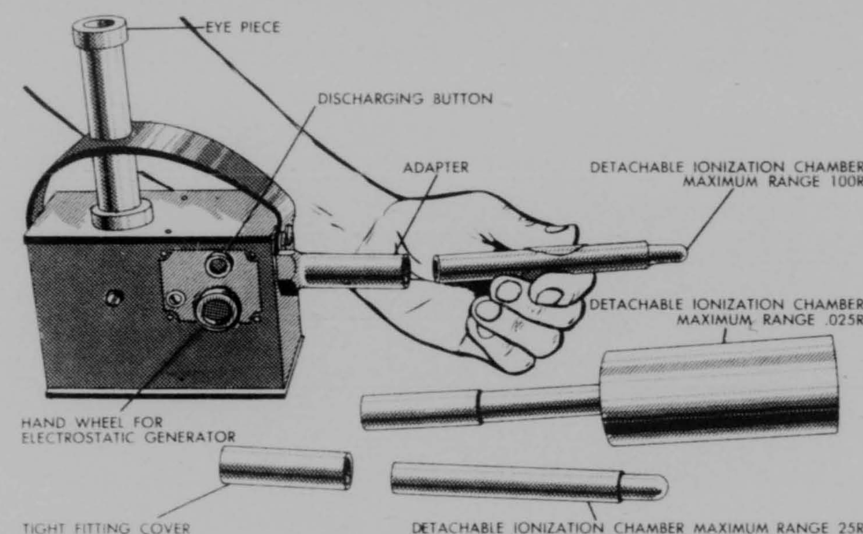


Figure 8–10B. Condenser r Meter,

ers in cyclotron laboratories and x-ray laboratories for years. The instrument does, however, have some disadvantages. It is difficult, due to the rather small size of the insulators, to prevent leakage of charge in damp climates. Also, if the instrument is dropped it may discharge itself.

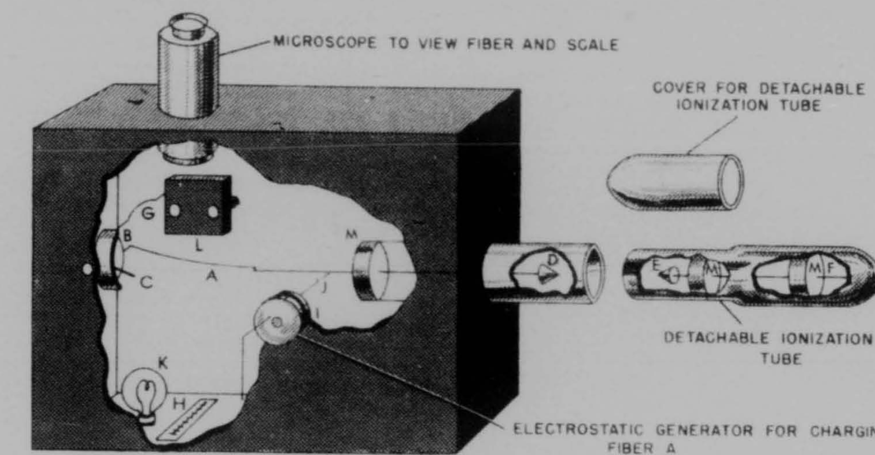
Film Badge

There is one more dosage-measuring device. This is the film badge. It is the lightest and cheapest of all. It is, at least in theory, simplicity itself. Ordinary dental x-ray film is used. The film is partially covered with a piece of thin lead sheeting. It is carried in the pocket for a time and then developed. The amount of blackening of the film is a measure of amount of radiation to which the wearer was exposed during the time he carried the badge. It is obvious that this device measures the total radiation.

As has been noted, this device is light in weight and cheap. It has another great advantage. In itself, it constitutes a permanent record of the amount of radiation to which the wearer was exposed during the time he wore the badge. Further, this record has been admitted in evidence in the courts. However, the film badge does have some disadvantages. The technique used in developing the film is critical and if not followed precisely errors can be introduced. Also, the film manufacturers have not succeeded in standardizing their film and each lot of film must be calibrated before it is used. Even so, the film badge appears to be the only instrument which is now available for large numbers of individuals. The films were widely used at Bikini and Sandstone.

Calibration of Radiation Instruments

All of the devices mentioned must be calibrated. This is not a difficult process. The instrument is placed a known distance away from a small sample of radium. About one milligram is sufficient for the Geiger-Mueller but not for the ionization chambers. The reading of the instrument, at the point, is then taken. The instrument is then moved to a new location which is nearer, or further, from the sample and process is repeated. In this fashion a series of readings is taken. It is known that the intensity near the radium sample is given



A. MOVABLE FINE QUARTZ FIBER
B. BOW TO SUPPLY TENSION FOR FIBER A
C. SUPPORTS INSULATING BOW B AND PLATE L FROM CASE
D. AND E. TERMINALS WHICH MAKE CONTACT WHEN DETACHABLE TUBE IS INSERTED IN INSTRUMENT
F. IONIZATION CHAMBER
G. CONDUCTOR BETWEEN BOW AND PLATE PLACING L AND A AT THE SAME POTENTIAL
H. SCALE
I. ONE DISC OF ELECTROSTATIC GENERATOR GROUNDED TO CASE
J. SWITCH
K. LIGHT TO ILLUMINATE SCALE
L. PLATE
M. INSULATORS

Figure 8–10C. Condenser r Meter, Cut-away View.

by $(8.4 \times M)r^{2}$, where M is the mass of the radium sample in milligrams and r is the distance of the instrument measured in centimeters. This formula gives the intensity in roentgens per hour. The dosimeter, or the film badge, is calibrated by placing it in a position and calculating the intensity of the radiation in terms of roentgens per hour and then leaving for a measured time. In this fashion the total radiation is calculated, the film is developed, and the blackening produced in the particular lot of film by this amount of radiation is measured.

SECTION VI—SURVEY AND DECONTAMINATION PROCEDURES

1. GENERAL

Preceding sections of this chapter have presented the nature of atomic explosions, radiation hazards and radiation detection equipment. This section is devoted to a consideration of two additional major problems which confront personnel charged with maintaining our defenses against radiological attack, whether by atomic bombs or other means. These problems are:

The determination of whether or not radiological contamination of an installation, ship or area has occurred, and if so the type and extent. This is necessary so that the commanding officer may be appropriately advised concerning the employment of personnel and materiel and the extent to which rescue, evacuation, decontamination and salvage are necessary and possible.

The decontamination of personnel and materiel which have been subjected to radiological attack.

2. SURVEYS

In attempting to obtain and evaluate information regarding the degree of radiological hazard existing following an atomic explosion or other radiological attack it is necessary to conduct a systematic survey of the area involved. A few haphazard instrument readings will not suffice to give a clear picture of the degree and probable types of contamination present, nor will they indicate the measures which should be taken for the protection of personnel remaining in, or likely to enter, the area. In general there are three types of surveys which should be included in any plan for obtaining the information desired:

A survey of meterological and terrain factors and of initial reports on the location and nature of the primary source of the hazard (i.e., atomic explosion, radiological dust, etc.). This survey, which can be partially accomplished in advance of actual attack, should lead to a quick prediction of the location of the "fall-out area." (Fall out is the downwind precipitation over an area of a vast number of very tiny radioactive particles from the radioactive cloud created by atomic explosion.)

A rapid survey of gross contamination in the local area, in order to determine the immediate safety precautions and rescue operations necessary.

A detailed and accurate survey over a considerable period of time to obtain information on the exact nature and rate of decay of the radioactivity present. This survey may include laboratory analysis of contaminated samples, and should be carried out.

Survey Procedures

Procedures involved in each type of survey may now be briefly examined:

Fall-out, previously defined, can be a source of hazardous contamination, varying greatly with the height of an atomic detonation and whether the detonation was over land or water or underwater. The calculation of the fall-out area is beyond the scope of this discussion, but can be roughly estimated by trained personnel, should be estimated at the command post or damage control center (nomenclature depending upon type of unit involved, and should be estimated under the direction of a meteorological officer. The predicted fall-out can be the basis for evacuating personnel from the estimated fall-out area before fall-out occurs and thus avoiding personnel contamination, or for warning ships or aircraft to stay clear of or evacuate the estimated fall-out area, whichever the case may be.

The second type of survey is the rapid analysis of gross contamination in the local area which may possibly proceed simultaneously with the first or fall out survey. This survey applies to either land or sea areas. Radiological defense officers must be capable of planning and carrying out such surveys. It is apparent, however, that in order to obtain a significant amount of data in a short period of time, it will be necessary to have a number of trained "monitors" to take measurements of radioactivity throughout the area suspected of being contaminated. These monitors usually will be enlisted men, well-trained in the use of instruments and in making accurate reports of the observed data. A monitor should also know how to interpret the results of his findings in a degree sufficient to be responsible for his own immediate safety, and that of others near him, should he find himself in a region of great radiological hazard. The instruments to be used by such monitors have been discussed previously. The subject of the organization and training necessary to carry out their mission will be taken up in a later period.

Monitors' Survey Procedures

Monitors should be assigned to each unit area on the basis of a grid system previously designated. Following radiological attack each monitor should proceed to, and conduct his

survey within, his assigned area with a high intensity survey meter, taking frequent readings, until he reaches an area in which radioactivity is above the military tolerance level. He should report his findings to the command post promptly and frequently by whatever means of communication is available, and must especially report the line of demarcation of military tolerance level, if it is within his area. If the monitor finds that he already is in an area above military tolerance then he should evacuate to an area of lesser intensity, warning others to do likewise as he goes. If he finds that his entire area is below military tolerance he completes the monitoring and reporting unless otherwise ordered.

Assuming that the rapid survey within any given unit area has been completed and that the monitor is still within his area or that he has re-entered an area where the intensity has decayed (fallen off) sufficiently to permit at least short duration operations, the monitor will proceed with the third type of survey, the more detailed accurate survey. This time he may use a more sensitive, lower intensity survey meter, such as a G-M type, taking readings at more locations and with greater regularity. It is important that he continue to report his results to the command post or damage control center. If there should be no radiation evidenced, except normal background count, within the area under survey, monitors must nevertheless make continuing surveys of their entire area if it lies within the region of possible fall-out. This is necessary in order to detect any later increase of intensity and thereby warn of approaching fall-out and possible hazard. It should be remembered that both positive and negative indications of radioactive contamination are of importance to the Radiological Defense Officer who is plotting the overall situation.

During this detailed survey the monitor should select some samples of earth, water, or small exposed objects and transmit the samples through his command post or damage control center to a radiological laboratory where they may be checked for type of radioactivity. In this way the presence of alpha radiation, especially harmful to the body when alpha emitters are absorbed internally, may be discovered. Alpha radiation cannot be accurately detected and measured by present day instruments even though these instruments meet the requirements of field usage. Laboratory analysis may also lead to certain conclusions as to the types of materials constituting the contamination procedures to be employed. This information, together with carefully recorded intensity readings taken at regular intervals at a few points specified by the radiological defense officer, will form the basis for calculating the time which must elapse before a radiologically hazardous area may be again safe for occupancy.

3. DECONTAMINATION

The subject of decontamination offers many problems. Research in the subject is continuing and some progress has been made in resolving the problem. At present the wisest counsel is to avoid contamination if physically possible. There is no practical means for destroying radioactivity. Since radioactive decay, a nuclear process, is entirely unaffected by chemical reactions, decontaminating solutions such as are used in neutralizing mustard-gas contamination are of little value in this new situation. Radiological decontamination has as its objective the freeing of an area from persistent radioactive agents. This involves the actual removal of induced radioactive isotopes, fission products and or unfissioned parts of the fissionable material of this bomb itself.

Principles of Decontamination

Currently accepted principles of decontamination include the following procedures:

a. **The immediate reduction to a minimum of that contamination of personnel and vital installations which cannot be or has not been avoided.** This may include **complete bathing, monitoring, reclothing, administering medical treatment**, where required, and **evacuation** of affected personnel, **washing and scrubbing down** exposed surfaces to free them of loose contaminating particles, and **temporarily covering short range (alpha, beta) emitters** with a coating, such as paint, which will provide at least a partial shield against the emissions. This will prove useful in shielding beta emitters, but not necessarily alpha emitters due to the very short range of the alpha particles.

b. **Subsequent thorough decontamination of areas important enough and of low enough radiation intensity to warrant attempting such procedure**, which is likely to be costly and time-consuming. This may include **repeated scrubdowns, removal of closely adhering particles by chemicals such as citric or hydrochloric (muriatic) acids which render the particles more soluble, and the removal of the surface to which the particles are clinging by the use of paint-removing solutions, scraping or, possibly, wet sandblasting.**

The value of such operations always should be weighed against the possibility of temporary or complete abandonment of the area or installation, or of prescribing certain maximum periods of working time for personnel absolutely required to enter dangerous areas.

The Prevention of the Spread of Contamination

This is accomplished through **preventing access to particularly "hot" areas by proper isolation which will include plainly marking off dangerous areas, using great care in disposing of grossly contaminated objects** and the waste water and waste materials used in removing contaminating particles, **carrying out a carefully prescribed ventilation doctrine** in the case of ships or air-conditioned shelters, and **improvising a "change station" or "decontamination center"** for the thorough decontamination of personnel and of their clothing and equipment before returning to a clean or uncontaminated area after exposure to possible contamination. Contaminated personnel must wash themselves, possibly many times, until, upon being monitored, their bodies are found to be at a safe level (e.g., at Bikini—twice background count.) Clothing must be changed and the contaminated clothing laundered, or if repeated laundering fails to decontaminate, must then be destroyed.

4. SUMMARY

Considerable original thinking and experimentation is still needed in order to give practical answers as to what corrective measures can be applied in future situations involving radiological hazards. Current and future development of radiation detection equipment probably will result in more practical and more effective instruments than those now available to assist the monitor in the conduct of a radiological survey. Surfaces of such smoothness and low porosity that they can easily be decontaminated will be developed for structures and equipment, or perhaps surface finishes which can be removed when necessary, carrying the radioactive particles with them, may prove one answer to the problem of radiological decontamination. The student should seriously consider these problems. He also may be assured that research on these matters is continuing, both in the laboratories of the Atomic Energy Commission and in such installations as the U. S. Naval Laboratory in the San Francisco Naval Shipyard, which is endeavoring to shed light on the best methods and materials to use in decontaminating radioactive surfaces.

SECTION VII—DESTRUCTIVE CAPABILITIES OF AN ATOMIC WEAPON

1. THEORETICAL EXAMPLE

It is important that one appreciate the real power of an atomic bomb, and the purpose of this section is to present a realistic picture of the damage which a typical American city might suffer were such a bomb detonated above it. Without going into a detailed study of the problem it will be assumed that an atomic bomb, twice as powerful as the type

used against Nagasaki, is detonated some 2500 feet above the center of City X. City X may be thought of as one of our typical industrial cities with a population of over 200,000 people. With the foregoing facts in mind, it is possible to examine what would happen to X if it were subjected to attack. Let us assume that the attack takes place at noon when the downtown area is most heavily populated.

Initial Damage

The city is enjoying a pleasant sunny day with a cooling breeze coming in. The streets are thronged with thousands of shoppers in the downtown and "point zero" areas. Then suddenly and without warning the bomb is detonated high above the city.

A dazzling bluish-white flash blinds those people on nearby streets and sears them at the same time with its million-degree heat. Almost within a thousandth of a second the small ball of fire shoots out to form a sphere of flame one hundred yards in radius. Simultaneously the color of the ball changes, going over to a varicolored seething mass which spreads outward and downward at terrifying speed. Above it all, a huge pinkish white mushroom "atomic cloud" forms and climbs toward the stratosphere.

Directly under the blast, the instantaneous flash of heat sears all pedestrians into unidentifiable charred and grotesque forms. Those shielded from the heat are momentarily conscious of a terrible pressure wave that topples taller buildings and crumbles others into rubble. Within a second a blast wind of near supersonic velocity rushes in and demolishes these buildings untouched by the primary blast wave. The air is thick with dust from pulverized buildings and the crashing of surrounding buildings creates a din which is soon followed by the ominous noise of fires ignited by the flash.

Secondary Damage

To feed the multitude of fires, air rushes in from the surrounding area, even overcoming the prevailing breeze, and so on a firewind of gale proportions sweeps the city. This unusual firewind persists for several hours and makes the entire area near the center of blast, inaccessible to what fire-fighting equipment is available. Streets made impassable with debris, the failure of the water pressure, disrupted communications all prevent fire fighters from reaching the stricken area

Within a three-mile radius of the center of blast, the number of dead and injured is staggering to the imagination. Those who were within one mile of the blast center, while still surviving, are living on borrowed time. When the brilliant flash of light occurred, those living within a mile of the blast center were exposed to a deadly dose of penetrating radiation. Unseen, unheard and unfelt these deadly rays penetrating the human tissue had left their mark. Perhaps the survivors would linger for a few days, or even a few weeks but they are doomed.

Much of the enormous damage is due not so much to the primary effect of the bomb but to the secondary effects. In this category, one would list fire damage, injuries due to collapse of fire-gutted buildings, deaths from burns, suffocation and lack of medical care. Much of the effectiveness of the A-bomb is due to is instantaneous and widespread action. A modern and efficient fire department, such as "City X" has, can cope with a few outbreaks of fire within the city, but when hundreds of fires are simultaneously started miles apart in an impassable area, it is a hopeless task to stem the on-rush of the holocaust. The fires will continue to burn until the next day, at which time it will be possible to re-enter the area, critically examine the ruins and evaluate overall damage. To insure systematic evaluation each type of damage must be analyzed separately.

Blast Damage

Since it is difficult to separate the individual effect of the shock wave from that of the blast wind, their combined effect will be considered.

Damage at Point Zero.

From the center of blast to a distance of one mile there is heavy blast damage. All frame and brick buildings are demolished and only those sturdy, reinforced-concrete struc-

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tures on the periphery of this zone escape complete destruction. Within the zone the interior of all buildings is subject to intensive damage. Both the downtown and the Point Zero shopping centers on the periphery of this zone sustain extensive damage ranging from total destruction to heavy damage. In some cases the walls of the buildings remain standing but the roofs and floors are missing. Able Street is a scene of utter desolation. From the City Hall to Baker Street it is impassable. Streetcars and automobiles, many with their occupants lying dead inside them, stand out in the rubble-strewn streets.

Damage One Mile From Point Zero.

Farther out from the center of the blast, within the one- to two-mile radius, heavy damage is sustained. Included within this zone is the downtown area of the city. Here some of the larger, well-built structures seem to be intact but closer examination shows that their interiors are extensively damaged and many are gutted by fire. At the lower end of Main Street, the beautiful Memorial Auditorium is in ruins, but many of the buildings along Main Street even closer to the center of blast are almost untouched. Apparently these were shielded by other buildings or merely escaped blast damage by virtue of having been "skipped".

The neon beacon high atop the Charles Building has been ripped asunder and lies in the street below. The main structures remain more or less intact with greatest damage being apparent on the upper part of the building. In spite of the appearance of the exterior of the modern structure, there were many casualties in it and due to the fires which raged throughout the downtown area it was impossible to evacuate all of the occupants of the building.

To the east, the Central Terminal still stands, but severely damaged. Without any shielding from the blast wave, parts of the structure collapsed. The railroad yards are inoperable with twisted rails jutting up from the ground. Apparently many of the railroad ties in the bed were burned by the flash.

Damage at a Distance. Between two and three miles distance from the center of blast, moderate blast damage is evidenced among the ruins. Most of the blast damage is concentrated on frame dwellings and plants of light construction. Brick houses in this zone still stand but show some signs of interior damage.

More than three miles from the point of bomb detonation there are still signs of blast damage but for the most part they are minor and are masked by damage from fire.

It is possible for blast effects to be felt at as great a distance as eight miles from the epicenter, but such damage would be slight and rare.

Fire Damage

When the bomb explodes a vast quantity of radiant energy (light) is liberated in the form of ultraviolet, visible and infra-red radiation. This radiation causes intense surface heating of all objects which it strikes within a three-miles radius of the center of blast. In some cases, depending on the local conditions, this surface heating is sufficient to ignite the material. Thus, within a circle roughly six miles across, there may be hundreds or even thousands of fires started and of these several hundred will persist and spread.

The effect of such intense burning over such a wide area is to cause a mass influx of air from outside the region. This movement continues if it overcomes the prevailing winds and an enormously destructive fire-storm results and whole areas untouched by the blast are burned out.

In "City X" the prevailing southwesterly wind would overcome the fire-storm after a few hours and tend to sweep the blaze into the B section of the city. To the north, Forest Lawn and Dog Park would act as natural fire breaks and to the southwest, the South Park section would be shielded by the prevailing winds.

Effects of Radioactivity

All persons living within a radius of about $1\frac{1}{3}$ miles of the center of blast would be exposed to a lethal dose of radiation provided they were not shielded by thick brick or concrete walls. A wood-frame wall offers little

shielding from this radiation. Therefore most of the people surviving the combined effects of fire and blast in this area would probably die within a few days or weeks from the effects of the penetrating radiation.

Those living in the zone from $1\frac{1}{3}$ miles to 2 miles from the center of blast, while not receiving a lethal dose of radiation, would receive a considerable exposure that would complicate their recovery if they suffered any other injuries. Many would show obvious signs of radiation damage, such as loss of hair, but they would later recover and live apparently normal lives.

Outside of the two-mile radius, there would be no effect from the primary flash of radiation, but it is possible that a fall-out of radioactivity would occur. If so, varying intensities of radioactivity might be found ranging from harmless to dangerous amounts.

Village Y would lie directly in the favored path of the fall-out and if conditions were such that a rain storm occurred carrying down vast quantities of radioactivity with it, then the entire populace of Village Y and surrounding territory would have to be quickly evacuated.

It will be recalled that in the case of the New Mexico atom-bomb test, some of the atomic cloud settled out miles away from the detonation point and cattle in the path of this fall-out later were found to have white backs where some of the radioactive particles adhered.

Casualties

In summing up the supposed atom-bombing of "City X", one can most readily realize the terrific striking power of the new weapon by estimating the total casualties caused by the explosion—about 100,000. Of these, about 50,000 would result in fatalities. The number of fatalities would run as high as this because of the lack of proper medical facilities at the time they are needed most, i.e., the day of the explosion. At Hiroshima there were only a few hospitals in usable condition out of about fifty. Of 1780 nurses, only about 100 were available for duty after the explosion.

The staggering figure of 100,000 casualties would mean that every family in the city would be directly affected by the explosion. Many civic leaders, key industrialists, and thousands of skilled craftsmen would succumb to the disaster. Thus while the Section A steel plants would still be intact and outlying factories would be undamaged, the city would require many months before it could rebuild the bombed-out area, replace personnel, and repair public service throughout the stricken community. "City X" would have been effectively knocked out by one bomb!

SECTION VIII—ORGANIZATION AND TRAINING FOR RADIOLOGICAL DEFENSE

1. ATOMIC ENERGY COMMISSION

The Manhattan District was responsible for the correlation of the effort which led to the production of the atomic bomb. This organization has now been dissolved, and its mission has been taken over by the Atomic Energy Commission. One difference should be noted: The Manhattan District had the mission of producing a bomb; the Atomic Energy Commission (AEC), however, has the task of providing weapons and developing atomic energy in the broadest possible manner. The AEC not only is interested in atomic weapons, but also in the development of atomic power, the use of radioactive tracers in medicine, the use of tracers in biological research, and a score of other problems. The AEC is responsible to the President (Figure 8-11.)

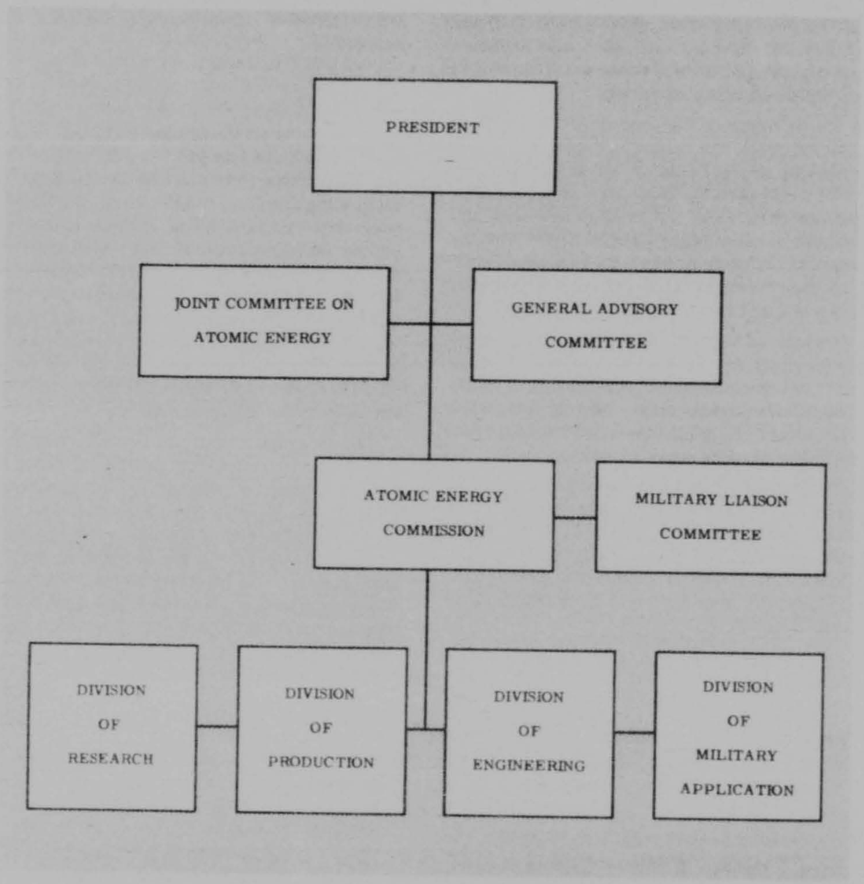

Figure 8–11. Organization of the Atomic Energy Commission.

2. POWERS AND RESPONSIBILITIES OF THE AEC

The broad powers and great responsibilities of the AEC are shown by the fact that it has divisions of research, production, engineering, and military application. It also includes a Military Liaison Committee, which has a twofold responsibility: to keep the military informed of any development in atomic energy that might be useful to them and to keep the commission informed of the needs of the military services.

3. THE AFSWP

The Armed Forces Special Weapons Project (AFSWP) has been organized to carry out certain military functions of the old Manhattan District, which were not delegated to the Atomic Energy Commission. These functions includes coordination within the three

components of the armed forces of their requirements for atomic offense and defense; training of technical personnel necessary in the armed forces for handling and delivery of atomic weapons; training and coordination of joint radiological defense; coordination of military development of offensive and defensive equipment between the armed services, coordination with the Military Liaison Committee to the Atomic Energy Commission, the Research and Development Board, and other high level agencies and staff coordination of joint projects arising in the military application of atomic energy development.

4. ORGANIZATIONAL REQUIREMENTS FOR RADIOLOGICAL DEFENSE

It is now estimated that the following personnel will be required in the radiological defense organization of the armed forces:

Radiological Defense Engineer

This title is applied to the officer who has graduated from the six-week Radiological Defense Officers Course and the three-year course consisting of one year at the Navy Postgraduate School and two-years divided between postgraduate work at a civilian university and field work. The field work is to be approximately seven months with the AEC or the AFSWP.

Radiological Defense Officer

This title is applied to the officer who has graduated from the six-week Radiological Defense Officers Course. This course, conducted under the supervision of the AFSWP, is intensive and difficult. The officer must have one year's college credit in physics, chemistry, and mathematics in order to meet the minimum entrance requirements for this course. It is highly desirable that he be a college graduate in engineering, physics, chemistry, or mathematics.

Monitors and Instrument Repair Men

These will be individuals who are trained to make radiological surveys and to use and maintain the radiation detecting instruments. They will not be well-trained in the underlying theories of radiation (nuclear physics) but they must understand instruments and how to use them. They must further be carefully trained in the personal protection techniques used in radioactive areas.

5. RADIOLOGICAL SCHOOLS

At the present time, as an interim measure, two types of schools have already been activated. The six-week course for radiological defense officers is being offered at Treasure Island, Army Chemical Center and Keesler Air Force Base. Classes of up to fifty officers were admitted to the Navy Postgraduate School in the fall of 1947. A new class will be admitted annually in July.

Proposed Schools and Courses

The final form of the joint training for monitors has not been determined. Consideration and planning on this problem, which is closely related to intraservice organization, is being conducted. Meanwhile, several experimental courses have been offered at Treasure Island to obtain information of future use in conducting this training. It appears likely that when such schools are opened, they will offer a four-week course of study organized to include instruments and their use and repair. The entrance requirements can therefore be much less stringent than for either of the other two schools. The problem of training monitors, and they inevitably must be largely enlisted men, is a big one. It must be decided whether they will all be trained at corps or army level, or air force or fleet level. It is probable that the first such schools will be set up at existing service schools where the training problem will be studied and plans made to decentralize such training. There is no possibility of setting up many such schools at the present time. Adequate numbers of trained instructors and instruments are not available. The problem of training monitors will be somewhat simplified by the advent of simpler and more rugged instruments.

The problem of training personnel of the civilian components is also being studied. The schools at Treasure Island, Army Chemical Center, and Keesler Air Force Base, are conducting two-week courses in radiological de-

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fense for reserve officers (Navy, Air Force, and Army). A series of extension courses is being drafted which can be used by the officer of the civilian components for the study of physics and nuclear physics. In a two-week course, he can be given the fundamentals of explosion phenomena, medical effects, and the use of instruments. It is likely that this procedure would graduate officers of the civilian components with training approximating that of the regular officer who has the six-week course. It should be mentioned that a part of this series of extension courses can be used by the regular officer as a review of his mathematics and physics before he enters upon the six-week course of study.

6. ORGANIZATION FOR RADIOLOGICAL DEFENSE

There is no firm policy at the present time covering organization for radiological defense. Each service has announced an interim policy, but any organization must be studied and tested in operation. It would probably undergo many changes before it becomes a firm policy. For this reason, such possible organizations will be only briefly discussed here.

Planned Naval Organization

The Navy has ordered a shipboard organization for radiological defense superimposed on damage control organization. They take the attitude that many of the problems of radiological defense are identical with those of defense against chemical warfare, and they have decided that the radiological defense shall be a part of the ship damage control organization. They plan initially to assign two trained monitors to each damage control party and eventually to train all damage control personnel to act as monitors.

Planned Air Force Organization

The Air Force favors a plan which is interesting and instructive. It is contemplated that a radiological defense officer, a graduate of the six-week course, will be assigned to the staff of a wing. He will be asisted by three enlisted men. Each group headquarters within the wing will have a radiological survey officer assigned, who will be equivalent to a Navy monitor. He will have two enlisted monitors as assistants. The airdrome group will have, in addition, three photodosimeter specialists, and the station hospital will have a radiological survey officer, two enlisted monitors, and three photodosimeter specialists. Each combat squadron will have two enlisted monitors as will most other squadrons. The maintenance squadron will have, in addition, nine instrument repair specialists.

Planned Army Organization

The Army has announced no plan as yet. From a study of the Navy and Air Force plans, however, such a plan can be sketched in broad outline. It is likely that the army commander will need a small radiological defense staff, headed by an officer who is a graduate of the three-year radiological defense engineers course. He should have assistants who are trained as instrument specialists, report writers, and monitors. It is likely that the special staffs of corps and divisions will have to have a radiological defense section. Such a section can be made small and could be headed by officers who are graduates of the six-week course. The question as to whether the regiment and battalion will require officers trained in radiological defense is being debated. It would seem that the Air Force plan might be a good one, and that regiment and battalion should have officer monitors. The smaller units will require sufficient instruments and trained enlisted monitors so that they can determine when the command is endangered by radiation. The commander must be kept informed of such hazards, and he should have the means at his disposal for making at least hurried surveys of limited areas.

There are many who believe that the problem should be given to the present gas and chemical officers. The radiation problem and the gas problem have much in common; there is a detection and a decontamination problem for both. The present Air Force system for defense against chemicals is well-organized, and it would be fairly easy to give the gas and chemical officers and airmen the additional training required and to increase their numbers until they could handle the new problems when supplemented by appropriate additional technical specialists at the proper level.

SECTION IX—COMMAND PROBLEMS OF RADIOLOGICAL WARFARE

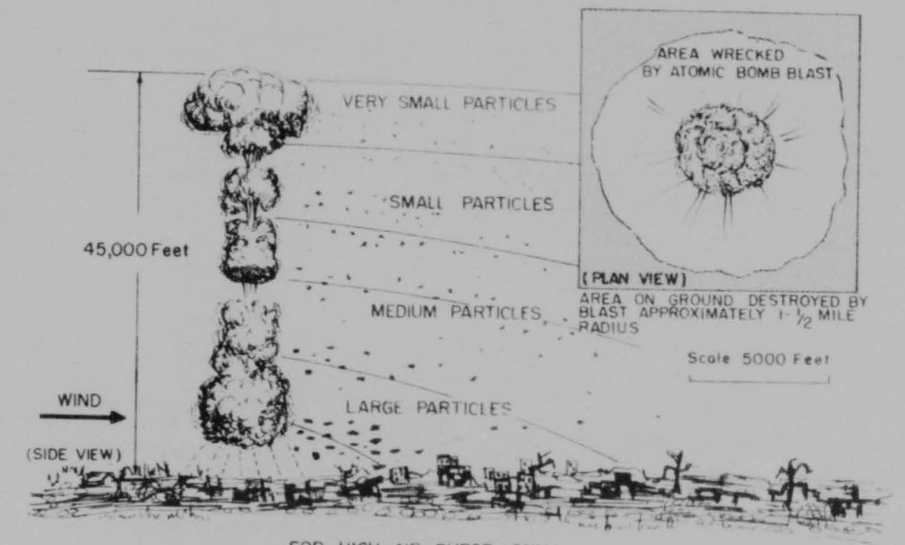

Figure 8—12. Airburst of Atomic Bomb and Areas of Destruction.

1. GENERAL

In the previous lessons, certain aspects of a new weapon whose order of magnitude and special character introduce new factors in the waging of war have been discussed. The purpose of this lesson is to emphasize certain command problems arising from the radiation hazard and present them from the commander's point of view.

Atomic attack, as has been indicated, may come in a variety of forms. Depending upon the method of employment, the extent and characteristics of the damage are generally known. There will be areas that are marked by atomic bombs for catastrophe, but not necessarily for doom. It is the problem presented by these areas that directly concerns radiological advisers.

Air Burst

In an air burst of an atomic weapon, the effects of blast, radiant heat, instant radiation, and secondary fires are predominant, while the radioactive contamination is relatively small and secondary (Figure 8-12.) In the downwind direction, areas will be found contaminated by fall-out of radioactive material; the degree of this type of contamination may not be a primary hazard.

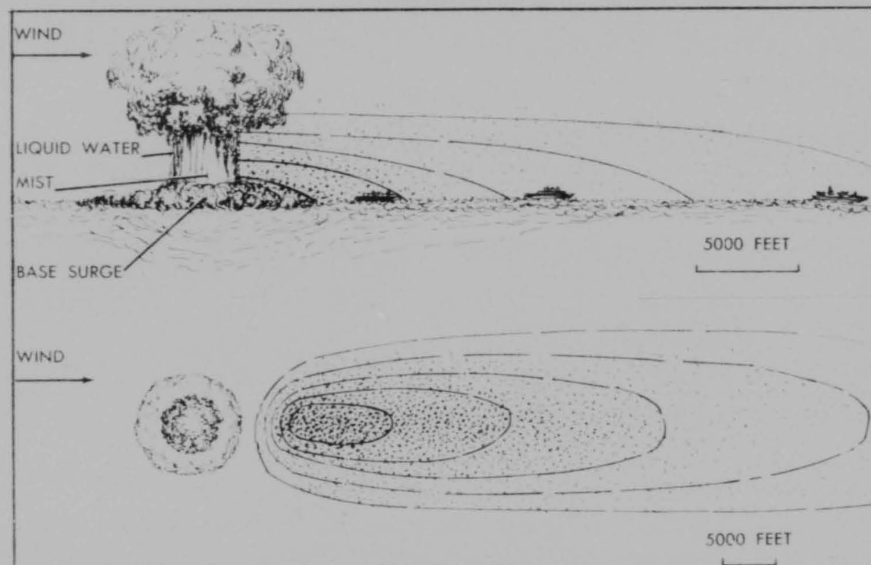

Figure 8—13. Underwater Burst of Atomic Bomb.

Underwater Burst

In an underwater burst, the effects of radioactive fall-out contamination and water-propagated blast are predominant and constitute an extremely serious threat (Figure 8-13.) The effects of instant radiation, air blast, radiant heat, and secondary fires are absorbed, shielded, or minimized by the water. In order to obtain an extremely large volume of highly radioactive material on a target, the effect of blast and heat is reduced. Should the underwater burst occur in sea water or a salt lake, the degree of contamination is tremendously increased by the fall-out of radioactive sodium.

The probable results of a sub-surface burst are purely speculative; however, one can arrive at some broad conclusions by analogy with the underwater burst (Figure 8-14.) The resultant radioactive contamination by the fall-out of soil-trapped fission products, plus neutron-induced reactions in the elements of the soil and, to a less extent, air and ground shock wave would be predominant. The instant radiation, radiant heat, and secondary fires would be secondary effects. Since the dissipation of the heat generated in a sub-surface burst could be expected to be slower than in an underwater burst, the cloud would rise higher and would be influenced greater by wind conditions.

Considering each of the effects of the various probable methods of employment of an atomic weapon, it is seen that they impose large problems on the military commander. If it is further logically assumed that the civilian defense organizations will no doubt rely strongly on the zone of interior commander for advice, coordination, and assistance, the task assumes huge proportions. For the commander outside the zone of interior, there may be a necessity for combining effort with that of a friendly power. This would further add to the responsibilities of that commander.

2. HOW A COMMAND MAY BE AFFECTED BY AN ATOMIC ATTACK

It is not the intention of this paragraph to emphasize the problem of radiation above all others, but to present the problem as one requiring judicious and thorough action on the command level.

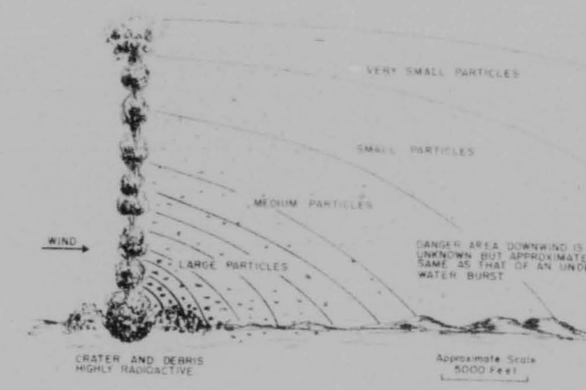

Figure 8—14. Estimated View of an Underground Atomic Bomb Burst.

Command Responsibility for Defense Requirements

At the present time, atomic warfare is experiencing a stage of development, calibration, and field testing. Much of the detailed work and specific tests is highly classified and will undoubtedly remain so for a long time. The results already known from previous tests impose new requirements upon our national defense organization and will eventually add to the specific responsibilities of our senior military commanders. These defense requirements cannot long be overlooked. Radiation can impose serious physical and psychological damage on a command not fully prepared to cope with it.

The most encouraging fact concerning the radiation hazard is that it has a workable solution, for, although the hazard is new and unique, our present military standard method of coping with conventional problems on the staff and planning level can adequately handle this new problem with little or no change. Some additional and specially trained personnel may be required on the troop level.

Possible Means for Implementing a Defense Program

The initial impetus that might energize a commander into implementing a radiological defense program could occur in any of several ways. He may be influenced by one of his staff officers who has returned from some form of radiological defense schooling, or he may acquire the desire through close work with civilian defense agencies on parallel problems. More than likely, however, he receives a directive from a higher command broadly outlining a requirement to be fulfilled under a set of policy conditions. Assuming, therefore, that a directive is received, this lesson reviews the commander's possible actions with a view towards introducing command problems due to radiation hazard. The following discussion cites examples only.

3. EXAMPLES OF A COMMAND'S PROBLEMS AND SOLUTIONS

How does this new threat of radiation affect accomplishment of the command's mission? This is the commander's first question. He

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calls in his chief of staff and his radiological defense officer and, if possible, arranges for the presence of the radiological defense officer of his next higher command. At this conference, the command's mission is thoroughly reviewed, and the radiological defense officer is requested to submit the recommendations necessary to circumvent or minimize the radiation hazard. In all probability, the radiological defense officer is given a free hand to consult with other special staff officers on technical matters. In the event a radiological defense officer is not assigned to his staff, the commander assigns a suitably trained officer from within his command or, if none is available, proceeds as is customary in filling staff vacancies.

At the time the radiological defense officer submits his recommendations, the commander calls in his chief of staff and formulates a general policy based on the approved recommendations. The chief of staff prepares a staff memorandum informing the various staff members of the task to be accomplished and requests recommendations in order to form the basis of a command SOP or an organization bill.

Problems to Be Solved in Forming an S.O.P.

Personnel and Administration Considerations: Placement of the radiological tables of organizations. (For example, in the Navy, he would be in the damage control section; in the Air Force, under the chemical officer; and in the Army, in the chemical section.

Number and type of trained radio-logical personnel and their assignment.

Table of organization, either tentative, provisional, or approved, showing all radiological defense vacancies.

Roster indicating radiologically expended personnel

Stabilization of key radiological defense personnel in important positions.

Personnel requests by specialty to fill vacancies.

Intelligence and Security Considerations: Establishment of a policy on the amount of classified information absolutely necessary to disseminate to accomplish the task. (In most instances, this limitation may be unnecessarily restrictive).

Manner of reporting areas of radiation contamination for intelligence purposes.

Procedure of reporting by subordinate units of new or unexpected means of employment of atomic weapons by an enemy.

Countersabotage and countersubversive plan.

Dissemination of information concerning the enemy's capability of employing atomic weapons, including possible targets, means of employment, and timing of attack.

Plans, Operations, and Training Considerations: Requirements for personnel trained outside the command (radiological defense officers, instrument repair technicians, and radiochemists).

Specialized training requirement for the command, such as monitor training, decontamination training, and photodosimetry training (all training to be done at specialist schools).

Training within the command, such as general indoctrination, unit training, combined training, and exercises.

Operating procedure for monitor teams and decontamination teams.

Establishment of an alarm system.

The alert plan and active defensive plan.

Supply, Logistics, and Evacuation Considerations: Instrument, special clothing, equipment, and special supply requirements.

Replacement and repair requirements.

Special storage facilities, such as conditioned rooms for instrument repair and storage, and dark rooms for film badge processing.

Provision of decontamination equipment and estimate of supply requirements.

(A number of special staff officers will be affected by the new requirements of radiological defense in accordance with specified policy or the wishes of the commander in the absence of specific instructions).

4. REQUIREMENTS OF PERSONNEL IN RADIOLOGICAL DEFENSE

Radiological Defense Officer

The radiological defense officer would act primarily as a staff adviser in radiological defense, and many of the operating procedures would be based upon his recommendation. He should have a thorough knowledge of the policies of his commander and should be acquainted with subordinate commanders and their units. He should be an active, well-informed assistant to the commander and a helpful adviser to subordinate commanders. His main responsibility is to insure that all necessary and feasible radiological defense measures are implemented and efficiently carried out.

Medical Officer

The medical officer would primarily be interested in the health and physical condition of the command. He may provide for the development of film badges and maintain exposure records on members of the command, if so designated. He advises the commander when radiation exposure constitute a damaging physical hazard. In accordance with directives from higher authority, he establishes the exposure limits for the command.

Construction Personnel

The construction personnel would supervise the construction of installations required for radiological defense. The engineer also consults with the radiological defense officer concerning the optimum protection to be gained through special types of construction and the location of new construction.

Communication Officer

The communication officer would probably be responsible for providing storage and repair of instruments on the command level. He might also receive and issue, in bulk, film badges and photodosimetry equipment. He also may be required to provide photographic dosimetry facilities.

Other Officers

The many other special staff officers would have individual problems which would be worked out by coordination with the radiological defense officer or by direct instruction of the commander.

After all members of the staff have submitted their recommendations, they are consolidated, and the operations officer translates them into an SOP or organization bill which forms the basis or foundation of radiological defense within that command. This plan gradually undergoes changes as it is repeatedly put to test or as the command receives new instructions, until it is eventually sound and practical.

5. SPECIAL PROBLEMS

A great deal of profitable information and guidance can be extracted from past experiences in operations involving large area radiation contamination.

A command problem which was potentially very serious arose at the Baker Test of Operation Crossroads. The Baker Test was different from Hiroshima and Nagasaki; water trapped the radioactive materials from the bomb and rained on the target vessels, producing an invisible hazard. Radioactive material was scattered over the decks of the ships. Men walked through it, tracked it around, and got it on their clothing and hands and faces. They could not see it, feel it, or smell it. They did not respect it, but they could eat it and they could inhale it.

Bikini

At Bikini, when it was realized that plans, group training, and operational techniques were inadequate to insure complete protection to personnel, operations could be brought to a halt. This lesson cannot be ignored, and for combat, planning and training must be such that an organization can continue to function.

Kwajalein

After the Bikini operation was discontinued, the target vessels were towed to Kwajalein and anchored in the lagoon for long-term storage. The need for further work on the vessels was apparent, and it was also evident

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that a complete quarantine of the ships would not remain practical. The ships contained large amounts of high explosives, including some experimental ammunition and some obtained from foreign navies. Removal of this ammunition would be necessary, and the longer operations were deferred, the more dangerous the work would become.

Frequent briefings of the men were held by the officers to impress the need for caution, not only against the dangers from radioactivity but also from the explosive materials they were handling. The protective restrictions which had been established were more severe than those used at Bikini. Every tendency to relax precautions had to be countered by a psychological campaign on the part of the officers to insure compliance. This is typical of what may be expected in the future. If the nature of the danger is not directly observable, the control of the troops will present a complex problem. There is a great difference between impressing a man with the **fear** of observable physical injury and **respect** for radioactivity. If **fear** of radioactivity is taught, the efficiency of atomic weapons will be increased. If proper **respect** is not taught, the toll of lives will be increased.

It seems that the command difficulties to be encountered and the lessons to be learned in atomic warfare will include a repetition of some of the difficult experiences at Kwajalein. There will be others that are more complex.

6. CONCLUSIONS

Sound principles demand that the value of any objective be weighed against the cost of achieving it. The new problem at hand can be recognized when consideration is given to the fact that the costs of achieving radiological objectives are not readily observable. When a man has been subjected to some cumulative absorption, which is referred to as "military tolerance," his radiological usefulness is impaired. Further exposure will entail an increasing probability of injury. When a commander has held his troops in an area of high radioactivity until he can observe the physical effects upon them, he had held them too long.

The commander of the future must have an understanding of the nonsensory hazards of atomic warfare and how to evaluate them accurately, and he must know how to pursue his objective without exceeding the normal, calculated risks balanced against the value of the objective. He must understand the nature of radioactivity and the slowness with which it acts and makes itself evident. He must be willing to accept the advice of a technical staff in such matters just as certainly as, under other circumstances, he would accept the advice of dispatches informing him of troop losses. He cannot shift to technical personnel the responsibility for failing to drive on to his military objectives, but he must give proper significance to the advice of such personnel. Military command remains in his hands and cannot be usurped by the adviser or the radiological monitors, but the commander cannot efficiently act in ignorance of the advice of such technical personnel, who in such instances would actually give far more advice. They would tell the commander the absolute facts, which he could not immediately see but which he could not ignore later when the toll was reported from the hospitals; facts which he could not ignore when his reserve troops would be demoralized and beaten without ever having faced an enemy.

During Operation Sandstone, just concluded, there was considerable evidence that the lessons of Bikini were profitably used and contributed to a very efficient, adequate, and commendable radiological defense operation. From Operation Sandstone will come additional valuable lessons pertaining to radiation, lessons that cannot help but improve and perfect the over-all concept of radiological defense.

CHAPTER 9—GUIDED MISSILES AND PILOTLESS AIRCRAFT

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SECTION I—HISTORY

1. GENERAL

The present technological revolution, superimposed on the industrial revolution, the growth of populations, and the rise of nation-states, has made war both "total" and "global" at once.

The technological revolution has brought with it four new and important weapons. These are the atomic bomb, the long-range plane, guided missiles, and the various biological agents developed for destructive purposes. They are not, of course, to be considered as the sole weapons of any future war. They supplement the more standard weapons and multiply the force of warfare to such a degree that future warfare is alarming to contemplate.

This chapter is devoted to the third of these new weapons, guided missiles. The military desire for a guided missile is perhaps as old as warfare, however, it did not become a practicability until the present era of electronics, and jet propulsion. Because the Germans have popularized so many new weapons, the idea is quite prevalent that they also pioneered in the development of guided missiles. Actually, the first crude guided missiles were begun during World War I by the United States. Shortly after the United States entered World War I, the Aviation Section of the Signal Corps became interested in the development of flying bombs. The leader in this field was the well known C. F. (Boss) Kettering of the General Motors Corporation who devised and tested a small biplane type of preset flying bomb. These early tests of 1918 and 1919 were not very successful and were subsequently abandoned. A most important result of these tests was the recommendation that any future work should be done with radio-controlled aircraft which could be given the necessary adjustments while in flight. This earliest known test showed that the preset type of missile was of almost no value. (As will be discussed later, the German V-1 and V-2 were very effective—when they hit the target area.)

As a result of the recommendations made on the early tests, the Engineering Division of the Army Air service in 1924, initiated a program for the development of radio controls. By 1928 attempts were made to fly a commercial-type Curtiss "Robin" monoplane by remote control. By 1932 this project had not produced any outstanding results and was dropped for lack of funds. From a guided missile viewpoint this program was perhaps not achieving the desired results, however, it did lead to the development of the very important automatic pilot, which was the forerunner of those used in modern aircraft. For six years nothing further was done in an attempt to construct a guided missile. Then in 1938, the Chief of the Air Corps directed that the development of radio-controlled, bomb-carrying "aerial torpedoes" should be continued. No satisfactory designs were submitted at this time; but through the sustained interest of Mr. Kettering and General H. H. Arnold the project was kept alive during 1938 and 1939. In 1940 a new set of military characteristics was initiated and a contract was negotiated with the General Motors Corporation for the fabrication of ten aerial torpedoes and related control and launching equipment. This was a major step in their development. Late in 1940, the Materiel Division of the Air Force embarked upon a greatly expended program which encompassed the development of a variety of remotely controlled targets, aircraft, and also offensive weapons of the guided missile type. The Equipment Laboratory of the Materiel Division was assigned the task of controlling this development work. Colonel George V. Holloman was in charge of the new Special Weapons Branch which was then established to handle the administration, development, and tests associated with these projects.

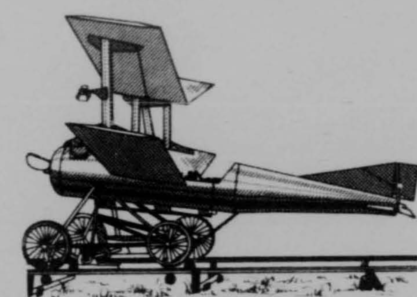


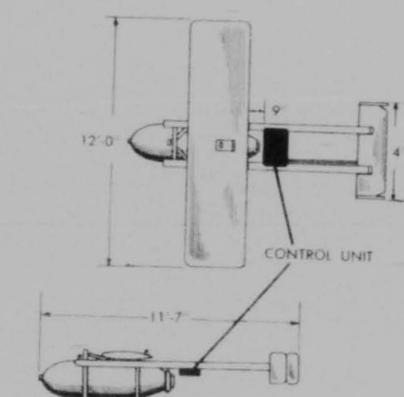
Figure 9—1. First Guided Missile (Pilotless Aircraft) Built in the U. S. Arcadia, Florida (Carlstrom Field—1918-19).

Among the several projects started at this time was the development of radio-controlled target planes, a glide bomb (GB-1), a controllable high-angle (free falling) bomb known as AZON, a "buzz bomb" (later called the General Motors "Bug"), another glide bomb known as the "Bat," and several other projects which were later discontinued.

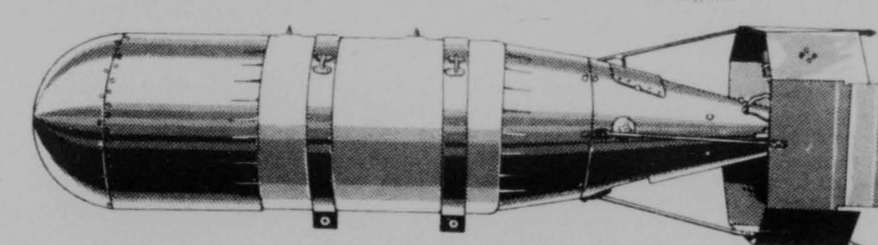
By September 1941 a group of engineers and technicians from Wright Field, augmented by technicians from the National Defense Research Council, and from the General Motors Corporation gathered at Muroc, California, to conduct the initial tests on the "special weapons" being developed.

The first of these "special weapons" to be tested was the GB-1 glide bomb. The object of this device was to enable a plane to drop the bomb at a considerable distance from the target, well outside the ring of heavy anti-aircraft fire, and have it glide to the target on its plywood wings. These early drops were made from a converted B-23 and the results were encouraging. During October and November of 1941, several of the "Bugs" were launched, several experimental AZON bombs were dropped, and a radio-controlled target plane (an old biplane trainer) modified with a tricycle landing gear, was flown. Because of the excitement caused on the west coast by the attack on Pearl Harbor the experimental group moved back to Wright Field. Here during the next three months they worked to improve and redesign various parts of the flight-control equipment which were used in conjunction with the "special weapons" being developed at that time.

Next the experimental group left Wright Field to continue their work at Eglin Field, Florida. In addition to the work which continued on those types already mentioned, they began work on the "Bat." The "Bat" project was successful and later was turned over to the Navy to undergo further development for use against surface targets.



BOMB, DEMOLITION, 2000 LB. M34



"AZON" BOMB

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During this same period, success was achieved with the GB-1 and it was ready for production by the early fall of 1942. The AZON tests had been continuing and in 1943 it was considered ready for tactical use. At the same time the "Bug" was successfully launched and radio controlled, but since this missile was quite complicated and costly to produce, the project was abandoned.

In the fall of 1942 and into the early months of 1943, work was initiated on a radio controlled version of the GB-1 Glide Bomb. The regular GB-1 was aimed by a bomb sight and after release flew on a straight line course to the target. The radio controlled version was intended to allow correction after the dropaway, thereby making it possible to hit a moving target and to permit a greater degree of accuracy.

2. DEVELOPMENT OF HOMING DEVICES

In addition to the earlier glide bomb projects, attention was also being focused on the use of heat, light, and radar homing devices to control the glide bomb. The GB-5, the GB-12, and the GB-13 utilized light-seeking homing devices which had been developed. Equipment utilizing light differentiation as a means of direction was under development by a civilian contractor as early as March 1941. Light-seeking devices continued in a developmental stage through 1943. During this period these various light seekers were not developed to a point of tactical utility. However, light seekers were sufficiently simple in design and construction, and offered the advantage that they could be produced quickly in comparison to other more complicated types of seekers.

The application of radar target-seeking devices to the glide-bomb vehicle represents a phase of the glide-bomb development toward which an appreciable amount of attention was directed by the Air Forces, the Navy, and various sections of the National Defense Research Council. In April 1942 the Air Forces requested that NDRC initiate a project to develop radar seeking equipment. Two types of this equipment, termed "RHB" (Radar Homing Bomb) and "SRB" (Send Receive Bomb), were eventually perfected for use on glide bombs. Sufficient quantities of seekers were procured from time to time to carry out the necessary testing programs for RHB and SRB. However, lack of technical personnel for the program, among other factors, slowed the progress of the work during 1944 and 1945. Both RHB and SRB were dropped to a lower priority in November 1944 because it was felt that the development had not progressed to a point where either equipment could be tactically useful in the near future.

With the conclusion of World War II the guided missiles program was greatly accelerated. To provide for the fact that there are basic differences between the aircraft program and the guided missiles program, formal recognition has been accorded the program by the establishment of various guided missiles offices.

3. OPERATIONAL USE OF GUIDED MISSILES BY THE UNITED STATES

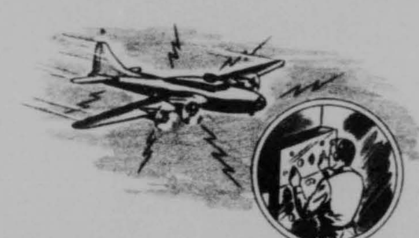
Prior to the end of World War II the Air Force had the following guided missile research and development projects, expected to be used in combat placed with industrial and educational institutions.

Jet Bomb

This missile was similar to the German V-1 weapon.

Abusive Project

A project which required the use of craft which had been equipped with radio controls, to be used on "one-way" missions with a full load of bombs, directed to the target by a mother ship and crashed into the target.



"WEARY-WILLIE" PILOTLESS AIRCRAFT

Figure 9–2. This Composite Shows Most of the Early Operative American Guided Missiles

GAPA Project

A project underway to build a weapon which could be used against enemy aircraft.

Vertical Control Bombs

These were the free-falling bombs of the AZON, RAZON and TARZON type.

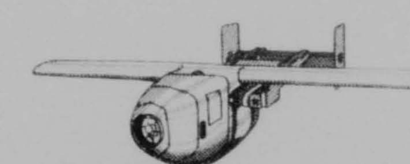
Glide Control Bombs

These were the glide bombs with or without control.

Glide Torpedo

Like the glide bombs this was a non-powered weapon which glided to sea targets—an airborne torpedo.

The Air Force guided missiles projects, in all agencies, prior to the end of the war totaled fifty-five. Of the fifty-five only the following were actually used in combat operations:



TELEVISION CONTROLLED GLIDE BOMB

GC-1—A glide bomb without control.

GB-4—A glide bomb with television control.

Abusive—Radio controlled aircraft.

GT-1—Glide torpedo.

VB-1—The AZON free falling bomb with aximuthal control only.

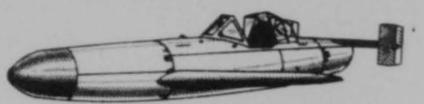
Many other guided missiles had completed the test and training stage and were ready for use when the war ended but were not used operationally.

This summarizes, briefly, the work in the United States Air Force, from the first experiments with guided missiles to the end of the war. While the program was progressing in the Air Force there was a considerable amount of work being carried on by other countries along these same lines, especially in Germany.

4. FOREIGN GUIDED MISSILES

As far back as 1932, German scientists and government officials realized the potential of rocket-propelled weapons. In that year, Walter Dornberger obtained support from the German Army to develop liquid fuel rockets for war purposes. Prior to that, other German scientists had done considerable research on rocket propulsion. Rocket research, however, should not be confused with guided missiles research. The principle of reaction (rocket propulsion) is at least two thousand years old, however, the ability to guide rockets or any other missiles while in flight is new. After the Germans had succeeded in building good rocket motors and jet-propulsion engines they turned to the development of guided missiles. They had previously tried with some success, the guiding of free-falling glide bombs by wire. However, their greatest achievements came in the field of the V-1 and V-2 missiles.

According to the strict definition of guided missiles as listed below, neither of these missiles qualifies as a true guided missile because neither could actually be guided in flight. However, the Germans were making great



JAPANESE PILOTED "BAKA" BOMB

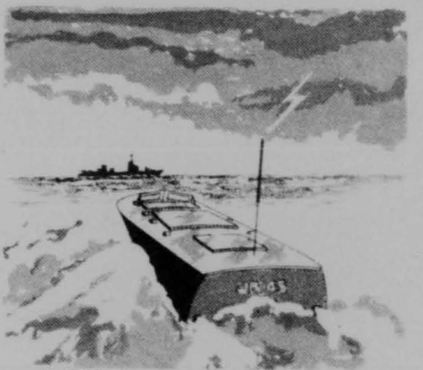
strides in this direction and it is believed that had the war lasted much longer they might have had a true guided missile in operation which could in all probability have changed or prolonged the course of the war. This fact has been reiterated by many of our military leaders, who have since viewed the work the Germans were doing at the close of the war. They had an air-to-air missile in the final stages of development which easily might have ended our air supremacy over Germany, had it proven successful.

The Germans had made attempts to control the supersonic V-2 weapon, but by the end of the war they had not been successful. Since the end of the war, American scientists have succeeded in controlling the weapon and probably our first really successful guided missiles will be similar to the German V-2 rocket.

The Japanese also attempted to introduce guided missiles into warfare. In the Pacific they used the BAKA bomb in some instances with great effect. This was a glide bomb having a small rocket motor for extra thrust. It contained a small warhead and was piloted by a "suicide" pilot. The missile was capable of being guided and might eventually have been used as a true guided missile. It could perhaps be classified as a powered glide bomb.

SECTION II—DEFINITION

Literally speaking most of the weapons known to mankind have been missiles of one form or another. Perhaps the oldest weapon was a stone thrown at an adversary. It might also be added that these missiles, prehistoric or modern, were guided in one manner or another. For example, when David hurled a rock at Goliath it was well-aimed or guided by a sling, which was in turn guided by his arm. When the earliest artillerymen, the crews of the ancient catapults, wished to control the range of their weapons, they plucked the leather thong which was used to pull the lever back and judged its tautness (therefore range) by its pitch. They too were guiding the missile in the crude, but very effective catapult. However, the term "guided missile" is now used more specifically. The missile is



T-BOAT RADIO CONTROLLED TORPEDO BOAT

considered to be a device for transporting a warhead to a selected target. By guidance is meant that the missile is controlled or guided after it has been launched. The official definition as prepared for the glossary of terms put out by the Joint Chiefs of Staff is as follows, "GUIDED MISSILE: a missile containing a device designed to steer and or change its acceleration in response to signals received during flight." (Dictionary of U.S. Military Terms for Joint Usage, dated 17 May 1948.) Even this meaning may be further defined.

A true guided missile is one which is not controlled by an automatic device which has been preset but by a device which is continually controlling the missile in its flight to seek out its target, and which can correct errors or change the course as the missile progresses along. For example: the V1 "Buzz Bomb," used so successfully by the Germans during World War II was a preset missile. Its course was set, corrections for wind were made, and the exact range (time in flight) were all precomputed. These data were then set on the controlling mechanism of the missile. When the bomb was launched from the ramp, or from the air, these timing devices made the necessary corrections. When it had flown its predetermined time, the fuel was cut off and the bomb went into a steep glide toward the target. If everything went as had been computed, the bomb would hit the target. But many factors, which occurred in flight, served to add error to error with the result that these missiles were very inaccurate. Changes in wind either increased or decreased ground speed, and altered the course. Variable airspeed characteristics of individual missiles changed ground speeds. Countermeasures either knocked many down or veered them off course. Therefore, these missiles were not really guided, but preset, missiles.

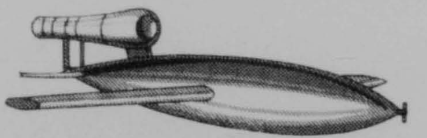
True guidance, furthermore, means that the missile is **continually controlled** and corrected without a human pilot during its entire flight to the target. "Continually controlled and corrected during flight" is a phrase which must also be further defined. (Actually on some missiles the control may not be applied until the missile is near the target; but it is capable of being controlled.) This control may come in three ways as follows:

Signals may come from an outside controller, or controllers, while the missile is in flight. In such a case a controller, or several controllers, would transmit impulses to the missile which would guide it to the target.

Signals may come from devices completely self-contained within the missile. In this case the internal devices pick up impulses from various sources and guide the missile during flight to the target. (This should not be confused with "preset" in which the devices do not "think" or react to various impulses; but do only what has been set on them prior to launching.)

Guidance as a combination of both methods. In this type the missile could be guided both by outside impulses and by its own internal mechanisms.

There are other kinds of so-called guided missiles which are continually controlled from the time of launching up to the time of hitting the target, which do not come within the scope of this course. These are land and sea guided missiles. The armies of many countries have used remote-controlled tanks as guided mis-



GERMAN "V-1" BUZZ BOMB

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Figure 9—3. "Homing" Device Directs Missile to Target.

siles and many navies have used remote-controlled torpedo boats as guided missiles. Perhaps these are rightly termed "guided missiles" but for the purposes of this text only those using the air or space as their zone of action will be considered.

To summarize, the definition of guided missiles as employed by the Air Force: a missile which (a) travels through the air, sometimes into space, which (b) carries no human pilot, which (c) is continually controlled, or under control (either from the outside or from internal devices) from the time of launching, during flight, and all the way to the target.

Target identification itself also may be a function of the missile. In some cases the target will be determined beforehand and the missile will be launched at the selected target. If the missile is controlled from the outside the controller will direct it to the target, but if the missile controls itself, it must have a means of locating and identifying its target. Many types of missiles are constructed to be guided in this manner.

In other cases the target may not have been determined beforehand. An example of this would be the use of guided missiles against enemy aircraft. The missile would be launched at the enemy formation and would then, either be controlled toward one of the aircraft, or it would direct itself toward one of these aircraft. For the latter method the missile must be capable of locating its own target.

SECTION III—GUIDED MISSILES DESIGNATION

1. OFFICIAL DESIGNATIONS

The following system of designating guided missiles has been officially adopted for joint Army, Air Force and Navy use. The basic designations shall be a two-letter combination of the three letters A (Air), S (Surface), and U (Underwater) in which the first letter designates the origin of the missile and the second letter designates the objective. This combination of two letters shall be followed by the letter "M" indicating "missile." The possible present combinations are:

AAM—Air-to-Air Missile
ASM—Air-to-Surface Missile
AUM—Air-to-Underwater Missile
SAM—Surface-to-Air Missile
SUM—Surface-to-Underwater Missile
SSM—Surface-to-Surface Missile
UAM—Underwater-to-Air Missile
USM—Underwater-to-Surface Missile

Each basic designation shall be followed by a service letter and the model number. For example:

A for Air Force
B for Army
N for Navy
ANG for joint use of the missile

Therefore, a missile designated as SSM-A-3b would be a Surface-to-Surface Missile of the Air Force, the third model of this series, and the second (b) modification of that third model.

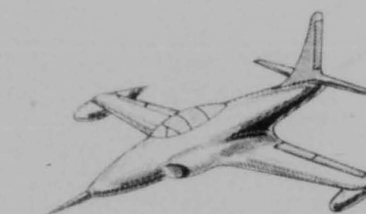
Furthermore, to designate the status of development of a missile, the following prefix letters shall be used:

X for Experimental
Y for Service Test
Z for Obsolete

If the above mentioned missiles were obsolete, it would be listed as:

ZSSM-A-3b

In cases where conventional aircraft are used as missiles, the standard or basic aircraft designation will be prefixed by the letter



MF-80—JET FIGHTER USED AS PILOTLESS AIRCRAFT

"M" to indicate "missile aircraft." For example:

MF-80 for an F-80 used as a missile

2. NORMAL CLASSIFICATION

The normal classification of guided missiles is based on the official designation as listed above. The present missiles all fall into one of the above categories.

Air-to-air—Offensive

This missile is used offensively by one aircraft against an enemy aircraft. It is launched from a friendly aircraft to overtake or intercept an enemy aircraft. Air-to-air offensive missiles may be guided by many of the guiding methods to be discussed later, and will probably depend most upon internal homing devices or beam riding devices, because at the very high speeds at which they must operate, a human controller would hardly be able to correct for any changes in course. These offensive missiles generally will be supersonic since they must be capable of overtaking the fastest enemy aircraft. In some cases the target may be other high-speed missiles. Air-to-air offensive missiles will perhaps replace the guns used on today's conventional fighter aircraft.

Air-to-air—Defensive

An air to air defensive missile is used by one aircraft to shoot down an attacker. It would be used primarily by bombers in place

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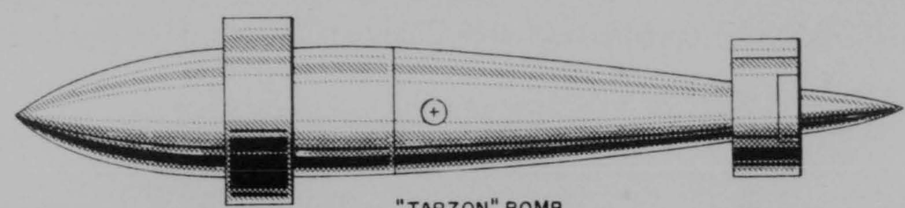


"TARZON" BOMB

of the turret guns which were used in World War II, principally to protect the bomber from fighter aircraft and other missiles in any type of combat. Air-to-air defensive missiles must also have supersonic speed to overtake the fastest enemy aircraft and missiles.

Air-to-surface

These missiles will be launched from aircraft at a surface target and their range will vary according to the mission and the type of missile used. The carrying aircraft should be able to remain beyond the zone of enemy anti-aircraft defenses. At the present time TARZON, AZON, RAZON, and the glide bombs (to be identified later) that have been developed are missiles of this type. For air-to-surface missiles to be most effective, their range and means of control must be increased and improved. These missiles generally will take the place of aerial bombs as used in World War II. The earlier missiles in this category will be subsonic but as they improve they will be supersonic for better results. To be effective these missiles will have to be very accurate, for they will be launched at a considerable distance from the target.

Air-to-underwater

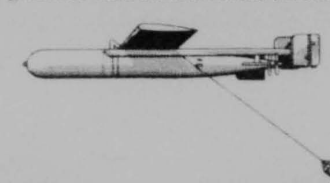
These missiles will be similar to the air-to-surface type described above, with the added capability of being able to operate underwater like a torpedo. These will be advanced models of the present aerial torpedoes.

Surface-to-air

This missile will be one of the most valuable of all the missiles under development. When scientists and military intelligence leaders went into Germany after the end of the war they found there the early models of the "Wasserfall," "Enzian," "Rheintochter," and "Feurlilie,"—all surface-to-air missiles. They stated that had the war lasted six months longer, or had our strategic bombing of German industry been less effective, the Germans might conceivably have rid the air over Germany of Allied bombers. This was not irresponsible talk, but was the considered opinion of experts. All of these missiles had been flight-tested and some had been given initial guidance trials. All of these missiles were supersonic but all development was curtailed because of the incessant aerial bombardment of Germany and the advance of the ground forces. Our 160 to 200-mile per hour "Fortresses" and "Liberators" would have had no chance at all against such opposition.

What might have been true of World War II will most certainly be an actuality if there is a World War III, because this type of missile has been improved over the work begun by the Germans, and probably will be operational in the near future.

These missiles are to take the place of anti-aircraft guns as they will afford much greater range than the standard guns, and with accurate guidance each missile should account for

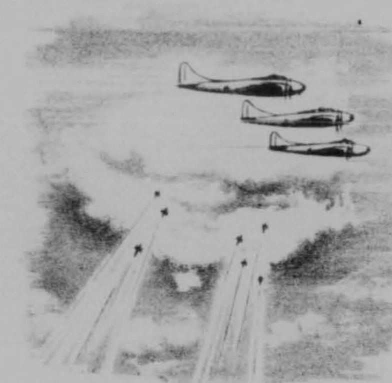


an aircraft. Because this missile can be launched from the ground and because it can be guided by several effective methods, it represents one of the "ideal weapons of warfare." A surface-to-air missile should be the perfect defense against the massed bomber formations of World War II, and when developed further should prove a valuable defensive weapon against other missiles.

Surface-to-surface

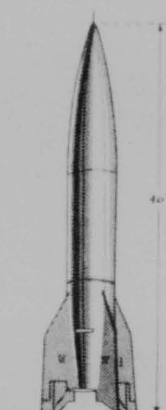
This missile perhaps represents the ultimate in weapons of war. When a missile is created which can travel 5,000 or 6,000 miles at a speed of approximately 10,000 miles per hour, and when this missile has been equipped with a guidance system which will deliver it on or very close to the target area, warfare certainly will have reached the "pushbutton" stage. Warfare then will have become so effective that after a few moments of such a war there could hardly be an opponent remaining.

Of course, the above represents the ultimate in a surface-to-surface missile. The first major attempt at a long-range missile of this type was the German V-1 "Buzz Bomb." This missile had a range of 120 to 160 miles, a warhead of less than one ton, a speed not higher than 400 miles per hour at an altitude of only 2,000 feet, and no guidance except for preset stabilizing and timing controls. The damage these missiles alone did in England during World War II was considerable, but the psychological impact of the German V-2 Rocket was even more devastating. One morning very early in September 1944 a stunning explosion sent hundreds of Londoners to their telephones to call the Ministry of Information for an explanation. There had been no air-raid warning, no sound of aircraft, not even the terrifying drone of the dreaded "buzz bomb." What had happened? To avoid giving aid to the enemy intelligence service the Ministry of Information told these callers that the detonation had been produced by the explosion of an illuminating-gas tank. The truth was almost too fantastic for belief. From a point on the European continent, perhaps two hundred miles from London, a cigar-shaped rocket forty-six feet long and six feet in diameter had been arched through space, reaching



GERMAN SURFACE-TO-AIR MISSLES
(ALL WERE IN PLANNING AND TEST STAGE)

an altitude of over fifty miles and a speed of 3500 miles an hour, before descending at a velocity many times that of sound upon a point within two miles of that at which it had been aimed. The V-2 rocket, as this second in the series of German vengeance weapons was termed, weighed fourteen tons at launching and consumed five tons of liquid oxygen and four tons of alcohol in its rocket motor. This



THE GERMAN V-2, MOST SUCCESSFUL ROCKET WEAPON OF WORLD WAR II

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nine tons of fuel had been consumed in the sixty seconds that the motor operated. This huge expenditure of fuel and the high cost of the rocket (in the neighborhood of $60,000) seems scarcely justified by the modest one ton of explosive which the V-2 carried as a payload. In addition, each of the 3,600 V-2 weapons launched against the Allies (2,000 at London and 1,600 at Antwerp) required six hours of elaborate preparation at the launching site prior to firing. And all of this effort despite the fact that the V-2, like the V-1, had no system of guidance in flight other than stabilization and fuel cutoff.

Weapons of the V-1 and V-2 type which are being tested today will be guided by several devices and will be much more reliable and accurate. The ratio of V weapons fired which were effective, to those which hit even close to the target, was never very high, yet they did considerable damage at no cost in lives to the Germans. Imagine what these same weapons could have done had they been more reliable and had they been guided accurately. This type will be the surface-to-surface weapon of tomorrow.

Already we have been assured of a range from five to six thousand miles; in the laboratories and on the proving stands the prototypes of these missiles are being tested. Elaborate guiding systems are being put into operation and will be ready by the time the missiles have been perfected. When fuels, temperature controls or safeguards, and methods for guidance are ready this long range "ultimate" in weapons will be ready for use. Even with the present developments the remaining technical problems are so complex that ten years would probably be considered an over-optimistic estimate on the length of time required to have these weapons in operational use.

Surface-to-underwater

This missile will be very much like the surface-to-surface missile described above with the added feature of being able to proceed to an underwater target after it has plunged beneath the water surface. In addition to being an aerial missile it will also be some form of torpedo. The surface-to-underwater missile will be used against enemy naval vessels both on and under the surface, and against enemy shipping.

Underwater-to-air

This missile will be similar to the surface-to-air missile with the added advantage that it can be fired from underwater and then after reaching the surface it will be able to launch itself into the air and seek out its target. This missile, like the surface-to-air missile, represents one of the ideal weapons of warfare, because the launching force is quite secure while the enemy would have little hope for accomplishment of his mission, or escaping.

Underwater-to-surface

Everything that was discussed about the surface-to-surface missile would apply to this missile with the additional advantage that this missile could be launched at a surface target from underwater.

SECTION IV—GUIDANCE SYSTEMS

1. ELEMENTS OF MISSILE GUIDANCE SYSTEMS

Tracking System

In order that the position of a missile in flight may be known at any time, a tracking system is used. If possible, the missile could be tracked by means of visual aids as in the case of a glide bomb. After a glide bomb has been launched the controller follows it visually and makes corrections as it drops toward its target. This system also might be used with surface-to-air missiles. The controller would follow the missile visually and make corrections with the aid of a computer. The weakness of visual tracking lies in the fact that it

is limited by the reflex time of the human controller, if the missile is being tracked for control purposes. However, in many instances the missile may be tracked merely to log its course.

A radio beam or radio direction finder may also be used for tracking purposes. In such cases the missile would emit radio impulses which would be picked up by the loop-antenna and would indicate on the radio compass the direction of travel, and could, by a method of triangulation, indicate the distance of the missile with respect to the receiving station.

The most advanced system for tracking missiles is with the use of radar. By means of a radar scope the missile may be tracked and have its direction and distance computed directly. The limit of this system is that radar range is "line-of-sight" or limited by the horizon, since radar impulses cannot follow the curvature of the earth. However, for a high-angle missile, radar could be used to plot the course for most of the trajectory.

Computing System

There must be a computing system incorporated into the guidance system of a missile in order that the controller, or the internal devices of the missile itself, may constantly keep the missile on its course at the right altitude and at the correct power setting (controlling acceleration or deceleration). This system would correspond roughly to a log kept by a navigator. It would record these data for the controller to aid him in correcting the course of the missile.

The computing system also might be given the task of determining the correct direction and distance to the target, especially if the target is moving. The computer would then contain a homing, or timing, device which would compute these facts and cause the guidance system to act accordingly.

The primary task of the computing system is to determine the course to the target.

Directing System

This system works directly with the computing system. If the missile is being guided by a controller he will direct the missile by means of this system. It may consist of a radio linked directly with the controls of the missile. In some of the missiles, planned direction was to be achieved by electrical means through a wire which was unwound as the missile sped toward its target. One advantage of using wire is that it cannot be "jammed." Whatever system is used, the directing system is that system which keeps the missile on its course.

2. CLASSIFICATION OF GUIDANCE SYSTEM

Initial

An initial guidance system will be installed to control a missile for the first part of its course. Usually this will be only for the early part of the launching or ascent, and will control the missile at its slower speeds. After the initial control, it will become inoperative. This system may be internal, acting merely as a stabilizer, or it may be operated by a controller who will direct the missile during the first phase of its flight.

Mid-course

The purpose of a mid-course guidance system will be to confine the missile to its predetermined course or flight line. This system also may be either internal or operated by a controller. If proper control can be achieved, this phase of the trajectory of the missile would benefit from a human controller, because he could make major corrections to set the missile on its proper course. After this the missile itself would perhaps make the quicker, "close-in" corrections, if properly equipped.

Terminal

This system would be responsible for the short range, "close-in" control of a missile at the time that it approached its target zone. A human controller would not react quickly enough during the close-in to make high speed corrections and the devices built into the missile would have to take over. This would most likely be a homing, or seeker, system of guidance.

3. TYPES OF GUIDANCE SYSTEMS

Present

(Although the latest definition of a guided missile does not include preset missiles as real guided missiles, there remains at the present state of development a place for mention of preset missiles.) The preset mechanisms are internal and must be set by the operator immediately before launching the missile, thereby performing three principal functions:

Stabilization. The preset device stabilizes the missile during its flight by a system of gyroscopic controls which act to prevent roll or dip in flight.

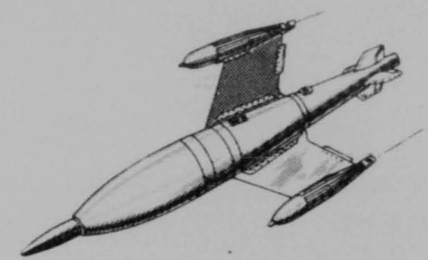
Flight Paths—Constant Altitude. This form of stabilization directs the missile on a prescribed flight path. An example of this was the V-1 weapon which maintained an altitude of two thousand feet to the target, for a given time, and in a given magnetic direction.

High Trajectory. This form of stabilization directs the missile on a prescribed trajectory which is designed to give the rocket the desired range. A timing device and a directional device direct the missile to a given target.

Command Guidance

This system employs a means within the missile for reception and execution of commands arising outside the missile.

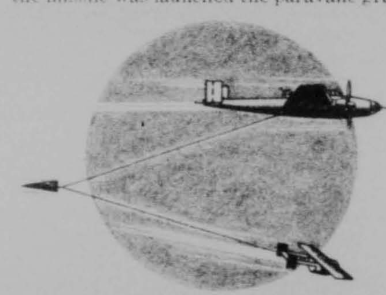
Wire. Some missiles have been designed with spools of fine wire which are unreeled as



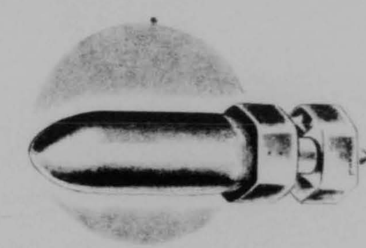
THE GERMAN X 4

the missile is launched for a distance of approximately three miles. Control of the missile is by direct electrical transmission along this wire from the operator to the control devices of the missile. The Germans had a missile of this type, the X-4, which was an Air-to-Air rocket propelled winged missile. The X-4 was a relatively small missile with a weight of about 132 pounds and was propelled by a liquid-fuel rocket capable of high speeds. The wire extended three miles giving the operator control for that distance. It had been tested and might have been a valuable air-to-air missile if the project had been continued.

There are records of a much earlier wire-controlled missile of the glide bomb type which was rather crude by present standards. When the missile was to be launched the wire was trailed out first by use of a paravane (like a wind sock). This paravane was on a wheel and pulley arrangement so that it stayed at the loop of the wire as the wire trailed out. When the missile was launched the paravane gradu-



EARLY GERMAN WIRE CONTROLLED GLIDE BOMB



RAZON AMERICAN BOMB WITH "TWO WAY" RADIO CONTROL

ally was pulled forward by the fact that the missile fell further and further below the plane, until the limit of the wire was reached. Control of the missile was again by direct electrical transmission.

Radio. Missiles designed to be controlled by radio are similar to those which are guided by wire in that electrical impulses are transmitted to the missile controlling its flight. Commands are transmitted to the missile by the controller who is directing it to the target. The early American missiles AZON and RAZON were radio-controlled free-falling bombs. As they fell toward the target they could be corrected in flight. In order to control these missiles the controller must have them in sight all the way to the target. In the case of AZON and RAZON each bomb was equipped with a very powerful flare which helped the controller follow it to the target. Radio control is limited by the ability of the controller to keep the missile on its way to the target and by his ability to keep it in sight by visual or other means. In operational use radio control runs into many troubles because "jamming" or radio countermeasures are so effective.

In the early days of World War II the Germans guided their bombers over England by radio beams. Soon however the English learned to divert these beams and to lead the German bombers astray. By 1941 the Germans had all but abandoned the radio beam system of guidance. Then by 1943 the Germans had perfected another system of radio guidance which used a number of wave lengths which permitted them to use radio-controlled glide bombs of the Heinkel type. Following this temporary success the Allies again perfected a means of jamming the system. The Germans then turned to the development of ultra-short wave control for their new surface-to-air missile, the "Schmetterling". As was stated earlier, had this missile reached the operational stage the Germans might have found the much sought-after defense against the Allied massed bomber attacks.

Each of the radio-guidance systems mentioned above is strictly a "command-guidance" system. It depended on a controller from the outside to do the correcting in flight. There are other radio-guidance methods not of this type which will be mentioned in a later section.

Television. A television system of guidance is closely allied to radio control, because the television device is used merely to aid the controller as he applies guidance by radio transmission. The television camera is mounted in the missile and picks up an image of the scene before it and transmits this information back to the operator, where it appears on suitable viewing equipment. By the appearance of this reproduced picture the operator can determine just how the controls should be moved to correct the aim of the missile. This type of equipment is suitable for self propelled missiles, glide bombs, or vertical bombs and has been tested in all three of these carriers.

At first thought this system seems to be the answer to the controller's problems. But missiles of this class have a number of serious limitations by being technically complicated, susceptible to "jamming" and interference. It is limited by the reflex action speed of the controller, which is a serious handicap to high speed operation and is satisfactory only against targets which are clearly visible on the screen. The proponents of this type of guidance, while admitting the above handicaps, point out the following very considerable advantages: First, it allows very accurate selection of the target or in some cases even the point on the target at which the bomb will be directed. Second, because this bomb is controlled by an operator, he may use his judgment in selecting the target and the path to the target, thereby avoiding decoys and perhaps interception. Of course, this re-

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quires a high degree of skill on the part of the operator.

These advantages, plus the availability of the equipment, make television an appealing aid to missile guidance and perhaps it will be used on many of the missiles being developed.

Direction Along a Beam (Beam Way)

For this system of guidance the missile contains all the guidance devices that are used. There is no human controller, therefore, no "command guidance." However, the beam is directed before and during the flight of the missile. A radio or radar beam is set up leading to the target. Then the missile operates somewhat on the same principle that is used by a pilot when he is making an instrument landing. The missile follows this beam, or perhaps more than one beam, to the target. In the case of radar beam the beam may be moved, steadily fixing itself on a moving target in the same way that it is possible to keep a flashlight beam on a rabbit running across a lawn at night. The radar impulses would then direct the missile to the moving target.

The great advantage of this system of guidance is that any number of missiles may be directed toward the target at the same time. The beam acts as a path along which these missiles are channeled to the target.

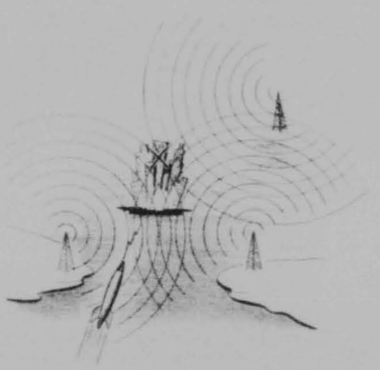
The disadvantage of the system is that most radio and radar systems are subject to "jamming," thus causing all the missiles to go astray and completely nullify the system.

Direction by Navigational Net

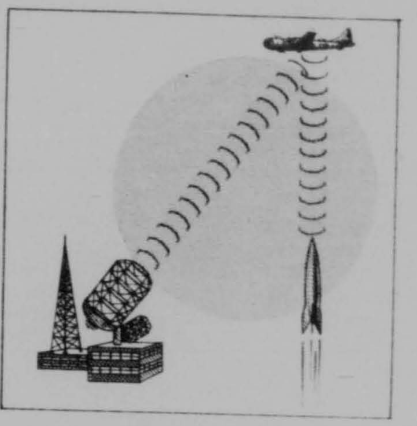
This system is closely akin to the beam way system. However, the missiles are set up to proceed along a course consisting of a series of radio navigational fixes rather than just along one beam. In this manner, it would be more complicated to jam because the enemy would have to jam every station in the net at all times. By this system the guidance equipment of the missile would operate in such a way that it would follow a series of fixes in its route to the target.

A more elaborate system of this kind is the Loran system. This is a long-range system which with present equipment is good up to eleven hundred miles, utilizing "master" and "slave" stations and accurate controlling mechanisms; but in operation it would be very effective, very accurate, and could channel any number of missiles to a given target. The "master" and "slave" stations could be widely dispersed and the launching sites need not be in the same area. All missiles would follow the same impulses and converge on the target zone, also the net could be swung so that an area target could be covered. In such a system the personnel at the launching station need have nothing to do with the localization of this rain of bombs on the target.

Another advantage of this system is that



LORAN CONTROL FOR GUIDED MISSLES



the bomb itself need not emit any signal which might give its position away to the enemy and it is also most effective in any weather. At the present time Loran navigation for aircraft is a proven, long range, all weather system.

Loran (Long Range Navigation) is, like radar, a discovery that was born of World War II but it must not be confused with radar. Loran makes use of long- and medium-length radio waves, the wave lengths on which ordinary musical or news programs are broadcast. On these waves Loran superimposes extremely short electrical impulses (one millionth of a second) emitted by several stations. Because of this method of transmission, Loran may be camouflaged as a musical program or as a news broadcast. This makes it almost impossible to detect. The only way that it could be jammed would be for the enemy to jam every broadcast that was going on, a stupendous undertaking.

Celestial Navigation System

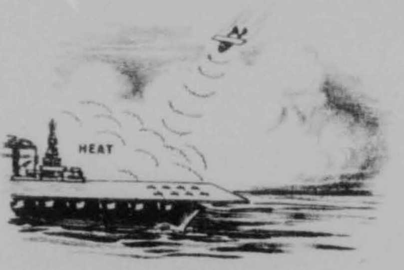
By this system the missile is equipped with an automatic device which calculates the position continuously by means of celestial navigation. In operation the route which the missile takes to the target would be set up in the missile. Then as it went along it would take continuous readings which would compare the present position with the intended position. The guidance mechanism of the missile would make any corrections that would be necessary. This system is being developed as a possible solution to long-range guidance problems. With the proper propulsion there is no limit to the range at which this type of guidance would operate. Another advantage is that there could be no jamming because there would be no radio signals.

Radar Navigation

A new type of radar guidance is being tested. This system is not dependent on radar to channel the missile to the target, but operates on a send-and-receive basis with self-contained equipment. The basic operation depends on the use of a "radar strip map." As the missile travels along the prescribed course, its guidance mechanism would "match the image" on its own scope with that of the strip map. In order for this system to be effective an extensive radar mapping coverage of target areas would be necessary. It would be of little use over ocean areas.

Homing Devices

A homing or seeking device consists primarily of a system which enables the missile to distinguish the target from the target background. There are many tested and operational homing devices integral with the missile which operate on the following principles. As the missile approaches a given target the seeker assumes control of the missile and directs it to the target. If the device is a heat seeker, it will lead the missile to the greatest source of heat in the vicinity. Similarly, if the



"HOMING" DEVICE—HEAT SEEKER

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device is a light seeker, it will lead the missile to the greatest source of light.

Heat (Infrared) Seekers. This type of homing device is sensitive to heat or infrared waves. The detector is capable of registering very minute quantities of heat, and of selecting the greatest quantity of heat from among a background of several sources of heat, such as the heat arising from large industrial areas, steel mills, oil refineries, etc. On a sunny day even large factories, railroad yards, railroad crossings, highway intersections, the center portions of long bridges, shore installations, docks, navy yards, etc., all give up enough heat radiation to attract these devices from a distance. These devices can become confused by a background of several thermal areas, or the atmosphere on a cloudy day may absorb or distort so much of the heat waves that the missiles would not be used to best advantage at that time. **Heat detectors are perhaps best applied to targets at sea where there is but one source of heat in a uniform background of the sea.**

Light Seekers. Another type of homing device is the light seeker. This device is set up to attract itself to the greatest source of light in the target zone. It consists of a type of optical instrument which scans the area and detects through photoelectric means the intensity and direction of a source of light. Through recent electronic improvements these devices have become extremely sensitive and can detect even the most minute amounts of light. When this light source is located, the mechanism within the missile controls the missile in the direction of the target.

Audio (Sound) Seekers. This is another application of the same idea. This time the detector is constructed to determine the direction to the greatest source of sound. This device would seem most ideally suited to detect aircraft and would probably be used in surface-to-air missiles with greatest effect. Here again a device scans the target area and determines the source of the greatest sound. Then having determined this source it would control the missile to this source.

Radar Seekers. This type of homing device operates by the use of radar. This system employs a radar transmitter to scan the target area. When the echo from the target area corresponds to the desired echo, or simply in some cases (surface-to-air) when there is an echo detected by the receiver unit, the control mechanism then takes over and directs the missile to the target. In some cases this might operate on the beam way principle, because a controller could direct a radar beam to the target and the missile could then "climb" along this beam to the target.

The guidance system is perhaps the most complex problem facing the engineer in this field today. The desirable guidance and control system will be determined by the traffic-handling ability of the system, by the range desired to control a given missile, the effect of countermeasures such as radio jamming on the control system, and the degree of accuracy which is desired of the system. Now that methods of propulsion have been improved to such an extent that even space travel is no longer referred to as something impossible, much of the over-all research and development in the guided missiles field is being concentrated on the guidance phase of study.

SECTION V—MISSILE PROPULSION SYSTEMS

1. GRAVITATIONAL SYSTEM

Gravitational propulsion is the simplest means of all. It requires no motor in the missile, depending entirely upon the gravitational pull of the earth. The force of gravity is constant, therefore, the time it takes the missile to reach the target can be computed very accurately. Of course, in order to use missiles which depend upon gravity as their only source of power, these missiles must be carried aloft by some other means. There are two types of gravity-propelled missiles: the free-falling missile, or bomb, and the glide bomb.

GLIDE BOMB LAUNCHING FROM AIRCRAFT

Free-falling Missile

The free-falling bomb or missile has no wings or other lift surfaces. It is controlled by a device in the tail. In operation, a free-falling missile must be dropped almost over the target and control is applied with just enough effect to make minor corrections. The AZON and RAZON bombs used by the Air Force during World War II were of this type, as is the new TARZON.

Glide Bomb

The glide bomb is wing supported. It may be released some distance from the target and then allowed to glide in on a course set by the controller or by the homing device in the missile. Glide bombs have been used in operation and have served as test vehicles for many types of guidance systems.

2. PROJECTILE SYSTEM

This is not a common type of missile and for the most part exists only on the planning table. However, control and perhaps even additional propulsion, added to the projectile of a big gun would have tactical significance. This form of propulsion arises from the detonation of powder inside the chamber of a gun. A missile of this sort would not have a motor.

3. RECIPROCATING ENGINE

The reciprocating engine is often said to be different from the reaction engine. Such a statement should be qualified by a study of the terms. Actually nearly everything that moves operates on the reaction principle. Following this mode of reasoning closely it might be stated that a reciprocal engine is a form of reaction engine. This would not be a false assumption but it would not follow the generally accepted idea that there are two major types of internal combustion engines in use today, reciprocating and reaction (rocket and jet propulsion). Common usage, therefore, separates the two. A guided missile powered with a reciprocating engine is one which is propelled by a standard aircraft engine. These are normally radial air cooled engines or types of liquid cooled engines. These engines turn a shaft which in turn drives the propeller. Some of these engines have utilized the thrust of the exhaust for additional power. Missiles powered with reciprocating engines are propeller-driven, and are subject to the limitations of the propeller. This means that they would fly at subsonic speeds and would not be efficient at very high altitudes.

Some of the earlier guided missiles were powered with reciprocating engines. The first guided missile attempt ever made was with a model designed by C. F. Kettering; this model was powered with a reciprocating engine. During World War II the "Wearie Willie" project was initiated to utilize modified conventional aircraft as pilotless aircraft to be directed to a target by radio control and then to be directed at the target in a crash dive. These ponderous pilotless aircraft were not very successful, so the project was shelved in favor of faster missiles.

One use of reciprocating engine pilotless aircraft which was very important was the target aircraft project, which used small fast radio controlled planes as targets for anti-aircraft training. With the speed of airplanes moving through the sonic stages at the present time even these target planes of tomorrow will be jet or rocket propelled.

Recent experiments with new type propellers have shown that it may be possible for a propeller-driven aircraft to exceed the speed of sound. This had always been considered beyond the limitations of the propeller. If this should prove to be feasible the propeller driven plane with a reciprocating engine, using ad-

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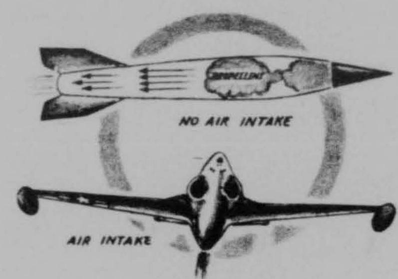


ditional exhaust thrust or perhaps a prop jet, would seem to be a valuable addition to our air arm. However, it should not change any of the plans made for guided missiles because the speeds sought here are so much higher.

The altitude limitations of the reciprocating engine and the propeller are also to be considered. In thin air, the efficiency of the propeller is reduced and the reciprocating engine, even with a turbosupercharger is not able to operate at its best. Long-range guided missiles are planned to fly at altitudes far exceeding these limits.

Another limiting factor on the use of the reciprocating engine for guided missiles is that the missile normally is scheduled for a one-way flight. Most reciprocating engines are so complex and expensive that they could not be used economically. Whereas, new jet engines such as the ram jet are very simple to construct and inexpensive.

4. REACTION MOTORS

Here again we must accept certain common definitions in place of the overall terms that are sometimes confusing. The "Dictionary of Military Terms for Joint Usage" published by the Joint Chiefs of Staff defines "reaction propulsion" as: "A propulsion system in which a forward motion or thrust is produced by the expulsion of propellent gases through nozzles or venturi, generally longitudinally opposed to the intended line of travel." This definition in effect draws a line between the reciprocating engine and the reaction engine although they both depend upon the reaction principle for their power.

Reaction motors are commonly considered to be rocket and jet motors. Many texts and many scientists use the term "jet propulsion" for both rockets and jets. Here again we find that the definition accepted for joint military usage draws a line between the two, as follows:

Jet Propulsion

"Reaction propulsion in which the propulsion unit obtains oxygen from the air as distinguished from rocket propulsion in which the unit carries its own oxygen producing material. In connection with aircraft propulsion, the term refers to a gasoline or other fuel turbine jet unit which discharges hot gas through a tail pipe and a nozzle, affording a thrust which propels the aircraft".

Rocket Propulsion. "Reaction propulsion wherein both the fuel and the oxidizer, generating the hot gases expended through a nozzle, are carried as part of the rocket (motor) engine. Specifically, rocket propulsion differs from jet propulsion in that jet propulsion utilizes air as an oxidizer whereas rocket propulsion utilizes nitric acid or a similar compound as an oxidizer".

The difference between jet propulsion and rocket propulsion then is principally the one fact that the **jet is dependent upon the air for its oxygen** and the **rocket carries its own oxygen** as a component of its fuel.

The recent ascendancy of the reaction motor as a means of propelling aircraft has done more than any other thing to hasten the development of guided missiles. Powered with a reaction motor the guided missile can now become a tremendous weapon.

The principle of propulsion for both rockets and jets is exactly the same. There is a common misconception that the thrust from a jet engine arises from the fact that a stream of air rushing from the nozzle of the motor pushes very hard on the mass of air behind the plane, and that this "push" drives the plane forward. If this were true, then a jet plane should take off quicker if it were backed up against a wall. If this is not true then, what is the explanation?

PRINCIPLE OF REACTION - FIRST PHASE-"A BODY AT REST TENDS TO REMAIN AT REST"

The following example will help to explain how the reaction principle operates. If you were in a small rowboat in the middle of a calm lake and you had no oars, how could you make this boat go? For this example we shall say that the boat is full of large boulders weighing around forty or fifty pounds each. If you wish to make the boat move forward, you pick up these boulders and throw them over the stern, one at a time. With each one that you throw over the stern the boat will get a slight push forward. This is reaction.

Where does the push come from? If the boat were backed up against a wall or some other fixed object, you could push against the wall and the boat would move forward, or away from the wall. But this was not a wall that you could push against which made the boat move, it was a boulder which you threw overboard. But the principle is the same. The boulder has mass, fifty pounds, and every mass has inertia. As you held the boulder in your hands before you tossed it overboard it remained there by its own inertia. You were merely overcoming the force of gravity. But when you threw this boulder, **when you accelerated it,** over the stern of the boat, you put force into your action. The force which you applied to the boulder to throw it overboard was equalled by a force of exactly the same proportion in the opposite direction which constituted the boulder's push on you, or resistance to your push. This force made the boat go forward. This is the force of reaction.

$(M_1 V_1 = M_2 V_2)$

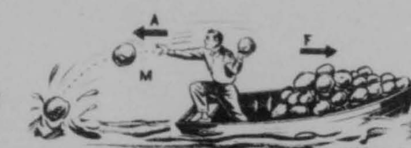
M_1 = Mass of boulder

V_1 = Rearward velocity of boulder

M_2 = Mass of man and boat

V_2 = Forward velocity of man and boat

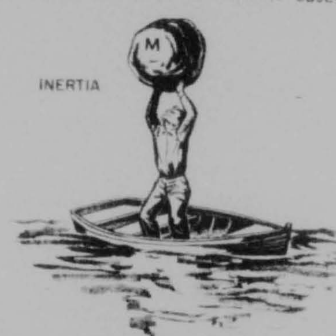
Furthermore if you just dropped the boulder overboard, you would get no force



PRINCIPLE OF REACTION - SECOND PHASE - "FOR EVERY ACTION THERE IS AN EQUAL AND OPPOSITE REACTION"

PRINCIPLE OF REACTION THIRD PHASE "THE PRINCIPLE IS READILY APPARENT WHEN PRESSURE IS APPLIED TO A SOLID STATIONARY OBJECT"

INERTIA



PRINCIPLE OF REACTION - FOURTH PHASE - A BODY AT REST HAS INERTIA AND THEREFORE WILL RESIST MOTION AND PROVIDE "PUSH" AS ILLUSTRATED IN (FIG 9-27)

PRINCIPLE OF REACTION-FIFTH PHASE "THE MORE THE MASS IS ACCELERATED, THE MORE PUSH IT WILL GIVE IN RETURN"

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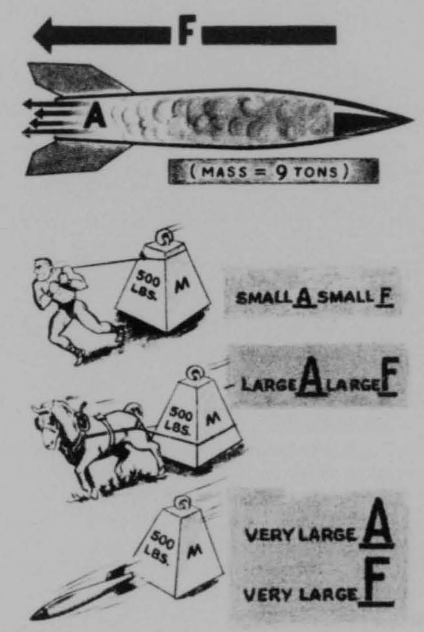
because you had applied no force. If you just tossed it in gently you would get a little force because you had put some push on it. But if you heaved it with all your might, you would get back an equal amount and you would find yourself catching on to the side of the boat to keep from falling, because the boat would be moving rapidly due to the acceleration from the reaction to the force that you had applied against the boulder.

This example of the boat (aircraft), the boulder (fuel and air), and you (motor) is directly applicable to guided-missile propulsion. Let us apply this to a German V-2 weapon. Here the missile (boat) contains in its tanks nine tons of propellent (boulder). When this propellent is burned by the rocket motor (you), this nine tons is expended (thrown over the rear) in from fifty-five to seventy seconds. This tremendous thrust drives this huge missile into the atmosphere at speeds up to 3,800 miles per hour. It is the same idea as the boat example. The thrust is the reaction to the force applied to throw this nine tons overboard in fifty-five seconds; it is not a result of a pressure of some sort built up outside after the gases have left the missile.

Returning to the boat idea again, we see that if you just barely push the boulder over the back of the boat, the boat receives only a little forward motion. That brings in another factor. The very important factor of acceleration. The basic law is stated, $F = MA$. This means that Force (F) equals the product of Mass (M) times Acceleration (A). If the mass remains the same (the size of each boulder is the same) then it is acceleration which must increase if you want to increase the Force. When you heaved with all your might against the boulder, you accelerated it as fast as you could. In return you received the maximum force that you, as the motor, were able to achieve. That was your rated thrust. Likewise with a rocket or jet. If the V-2, which weighs at take-off approximately fourteen tons, is to have the necessary force, or thrust, to drive it forward for 200 miles at the unequalled speed of 3,800 miles per hour, the relatively small mass of nine tons of propellent must be accelerated at the highest rate possible. This is why the type of propellent is most important. It must be a propellent which will burn

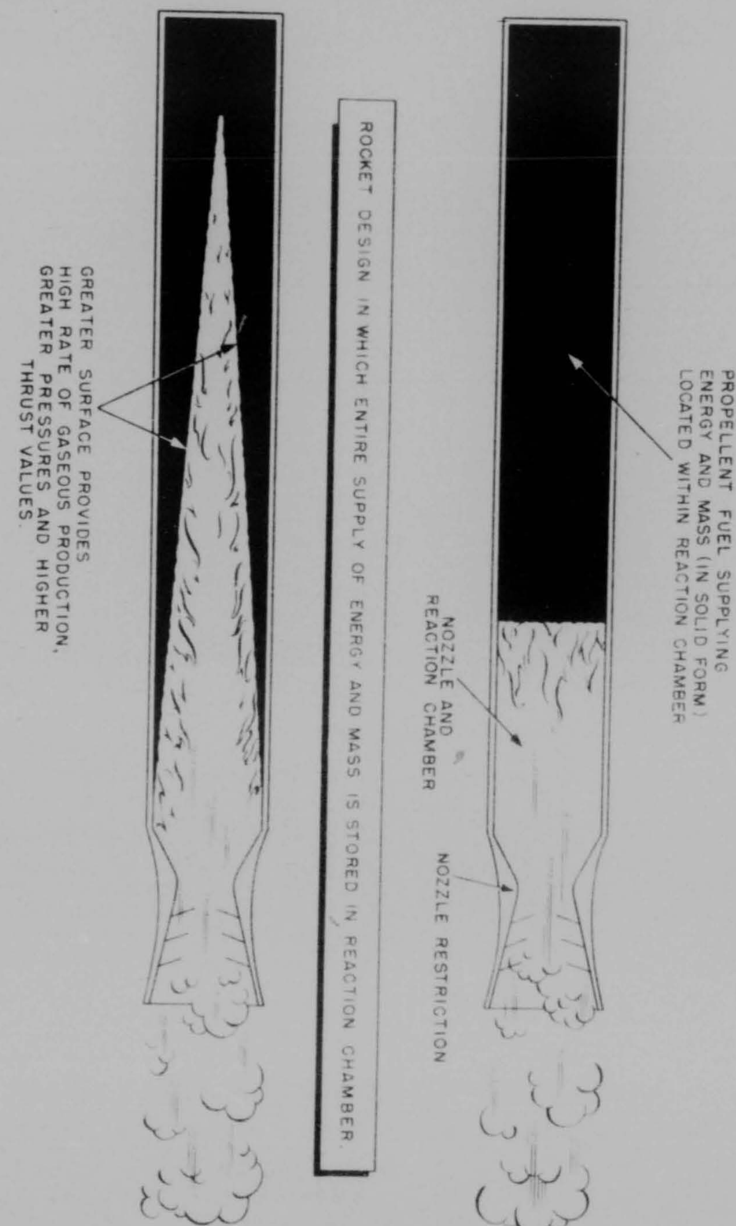


PRINCIPLE OF REACTION—IF THE MASS IS THE SAME, FORCE INCREASES AS ACCELERATION IS INCREASED

at a very high rate, rapidly enough to be consumed in fifty-five seconds, and will expand with high efficiency during the fifty-five seconds interval. The rapid expansion creates the very high acceleration required and drives the V-2 forward. The rapid acceleration is the key to successful rocket propulsion. The very high acceleration (a) multiplied with the mass (M) gives the high force (F) which propels these missiles at the highest speeds that have ever been obtained by man made objects.

Rocket Propulsion

The simple rocket motor is the easiest arrangement of all. A tube, packed tight with some slow burning powder and some sort of a wick to ignite it, is all that is required. Such a motor is centuries old. The rockets fired against Baltimore which provided the setting for our national anthem were old weapons of



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warfare in 1812. Today's rockets are a far cry from these powder rockets.

The modern era of rocket development dates back to the experiments of a Massachusetts college professor, Dr. Robert H. Goddard, who in 1914 began experimenting with rockets. After several experiments with powder rockets he gave them up as not practical for long range research, and devoted the rest of his time experimenting with liquid-fuel rockets. He is credited with the first successful take-off of a liquid-fuel rocket. This feat took place in Auburn, Massachusetts, on the 16th of March 1926. The history of successful rocket flight by liquid-fueled rockets dates back hardly more than a generation. It antedates the first solo flight of an airplane across the Atlantic by one year. Yet in this brief span, liquid-fuel rockets have led scientists to speak of thirty-minute transAtlantic hops, intercontinental rocket warfare, 6,000-mile controlled flights, and then even without hesitation the possibility of interplanetary travel, all because this obscure college professor had faith in liquid-fueled rockets.

Later, the Smithsonian Institute backed the work of Dr. Goddard and for a time the United States led the rest of the world in the field of rocketry. However, in the early thirties of this century Germany began to work with rockets, and several German scientists, backed by the army and the German government, experimented with them. In 1936 a great experimental program began and Germany made a bid for supremacy in the field of guided missiles. About this time, censorship was clamped down on German rocket development and not much was learned about their advances until they sent some of them over England in 1944.

A simple rocket motor is not very complicated but the liquid-fuel motor is something else. The main problem with a rocket motor is to convert the high pressure gases in the combustion chamber into a high-velocity jet. This problem is principally one of nozzle design. The shape of the nozzle through which the compressible gases are exhausted is important in determining both the mass flow and the exhaust velocity. The most common nozzle in use is the de Laval nozzle.

One should not get the impression that it is easy to design and construct a rocket motor just because the theory is simple. First of all the combustion of the propellent must occur in a very small chamber at temperatures higher than those occurring in any other type of heat engine, and that the high-temperature gases generated in parts of the motor reach supersonic velocities. In addition, the unusual chemical and physical properties of most liquid propellents introduced the designers to little explored fields of physics and chemistry.

There are three types of rockets, classified by the type of fuels used by each.

Solid Fuel. This type is known best as the ordinary fourth-of-July skyrocket. When the fuse is ignited it burns to the powder which in turn begins to burn. The slow-burning powder does not flash at once because it is not sealed, but burns continuously releasing a large quantity of gas at high temperature. The combustion of the powder builds up a high pressure in the chamber; in order to escape from the chamber the gases under pressure pass through the orifice of the nozzle at a very high rate of speed. To obtain the high speed the gases must be accelerated, the acceleration of the gases multiplied by the mass of the gases provides the thrust to drive the rocket into the air. The oxygen necessary for combustion is a part of the chemical content of the gunpowder itself. The rocket is not dependent upon the atmosphere for its combustion nor is it dependent upon the atmosphere for its "push", working most efficiently in a vacuum. This is true because, in a vacuum, the acceleration could be even higher than in the atmosphere as the atmosphere at any altitude has density and pressure which retards the emission of the gases from the combustion chamber.

The solid-fuel rocket became a familiar weapon as the "Bazooka" and as the airborne rockets which were slung under the wings of planes during World War II. These weapons travel at tremendous speeds and have great striking power. The military advantages of the power rocket are: the low cost of production, the ease with which they can be handled, and the fact that they are not easily affected

by temperature and humidity, if protected; they are easy to ship, store, install, and use.

There are disadvantages to the solid-fuel rocket which force it to play a minor role in the rocket field. First of all, unless they are packed very carefully, there is great danger that they will explode like a shell. More important, however, once the powder rocket has been ignited nothing can be done to control its combustion since it cannot be metered or throttled. This means that once the powder rocket motor has been started it will burn until all the propellent is exhausted. Also the impulse-weight ratio of the powder rocket usually is less than that of the liquid rockets. This means that over a given period of time the powder rocket gives off less thrust than the liquid rocket. The previous statement must be qualified, however, as a result of new secret developments. New propellents have been developed, and even with some of the common fuels the powder rocket was about as good as the liquid fuel rocket for the first forty seconds. After the forty seconds, however, the liquid rocket excelled.

In the field of guided missiles there will be few if any solid fuel rocket-propelled major weapons. However, the role of solid fuel rockets in warfare is increasing in other fields.

Liquid Fuel Rockets. As Dr. Goddard and the other early experimenters first learned, the liquid-propellent rocket offers the greatest promise in the field of long-range propulsion. At the present time the propellents used in liquid rockets are three or four times as effective as those used in solid-fuel rockets and better propellents are being developed. Today, one of the major problems is the motor. The very high temperatures and the extreme pressures which must be controlled at those high temperatures make the liquid-fuel rocket motor a very difficult motor to operate.

Essentially, a liquid rocket unit consists of a rocket motor, a propellent feed system, feed-system controls, and a starting system. In the feed system, one of the two schemes is generally used, a gas-pressure feed system or a pump-feed system.

A rocket motor consists of three parts:

Exhaust nozzle, which converts heat energy of the gases into kinetic energy by an adiabatic expansion process.

Combustion chamber, where the transition from the liquid phase to the gaseous phase occurs.

Injector, which introduces the propellent into the combustion chamber.

There are two types of liquid-rocket motors classified by coolant method.

Cooled (the propellent is used by the motor to absorb the heat generated).

Regeneratively Cooled. The coolant liquid absorbs heat as it circulates in ducts around the motor, after which the coolant is injected into the combustion chamber.

Film-cooled. Part of the coolant liquid is injected directly into the motor in such a way as to provide a coolant film on the inner wall surface of the combustion chamber.

Uncooled. The heat is absorbed by the heat capacity of the motor materials themselves.

Gaseous-fuel Rockets

Some consideration has been given to the development of gaseous-fuel rockets. The principle is much the same as in the solid- or liquid-fuel motor. Since very little has been published with respect to this type, we shall do no more than mention it here.

In the future, rockets should develop more efficiently. First of all, new propellents (fuels) are needed to give more power. Next, there should be improvement in combustion. Under ideal conditions today the motors are about 90 per cent efficient. New alloys and other materials are being developed for rocket construction which may withstand the temperatures and stresses involved. These materials must have greater strength at high temperatures and lower heat conductivity in order that the heat will not effect the entire missile. And finally, in order to give a higher pay-load ratio, new light weight motors will be developed.

Rocket propulsion certainly offers the

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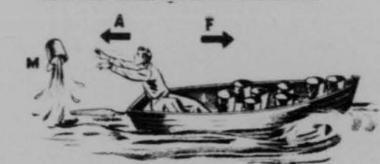
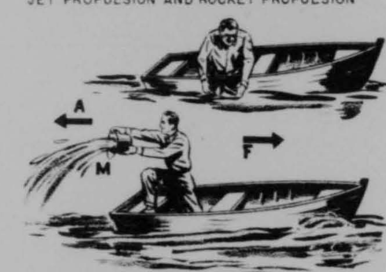
greatest source of power for guided missiles. Already scientists are planning for ascents of rockets beyond the earth's gravitational field. According to these authorities on missiles, there is little difference in design and performance of a space ship and an interplanetary rocket missile.



PRINCIPLE OF REACTION - THE DIFFERENCE BETWEEN JET PROPULSION AND ROCKET PROPULSION



PRINCIPLE OF REACTION - THE JET ENGINE ADDS TO THE MASS (FUEL) BY SCOOPING UP THE SORROUNDING FLUID

Jet Propulsion

The **"Dictionary of Military Terms for Joint Usage"** defines jet propulsion as "Reaction propulsion in which the propulsion unit obtains oxygen from the air as distinguished from rocket propulsion in which the unit carries its own oxygen-producing material." This definition points out the real difference between the two reaction-type engines as the fact that the jet engine is dependent upon the surrounding air for its source of oxygen, and for most of the mass which it accelerates. This means that even though both operate on the same principle, the jet could not operate in a vacuum because the fuel used must depend upon atmospheric oxygen for combustion. This implies that since the jet engine does not carry its own oxygen it operates without that extra load. This means also that the air, only 20 per cent of which is oxygen, provides the jet propulsion motor with a great mass of gas to be discharged from the exhaust, thus providing for the mass in the equation, Force = Mass X Acceleration. As an example, the J-33 engine in the F-80 utilizes $2\frac{1}{2}$ tons of air each minute. This mass of air is accelerated almost instantly by the engine from 0 miles per hour to 1400 miles per hour. The product of the mass ($2\frac{1}{2}$ tons) and the acceleration of the mass (23.3 miles per minute) gives the force or recoil, which drives the F-80.

The jet engine utilizing this mass of air at sea level where atmospheric density and temperatures are high, makes the engine relatively less efficient. As altitude is gained the mass of air processed through the engine per unit of time decreases. Thrust apparently is lost, but not in proportion to the decrease in the density. Acceleration increases due to the reduced pressure of the atmosphere at the exhaust.

Carrying out the previous example of the man in the rowboat, we might say that instead of boulders in the boat to produce reaction propulsion the man has buckets of water. As he heaves the water to the rear, he and the boat move forward — this is rocket propulsion. Now if he has only an empty bucket and scoops up water each time, and then heaves it over the stern, he and the boat will still move forward; this is jet propulsion. The water he scoops up corresponds to the mass of air which the jet engine scoops in, with the accompanying ram drag.

Jet propulsion engines are generally more complicated than rockets. In the more common types there is a compressor, a turbine, and other components. The compressor and turbine rotate at a very high speed. In fact, the high rotational speed of these units is so great that the gyroscopic forces which have to be overcome when the missile or aircraft changes course sometimes causes the engine to fail.

The turbine unit must operate at very high temperature, and except for a few special alloys no common metals will withstand the high temperature.

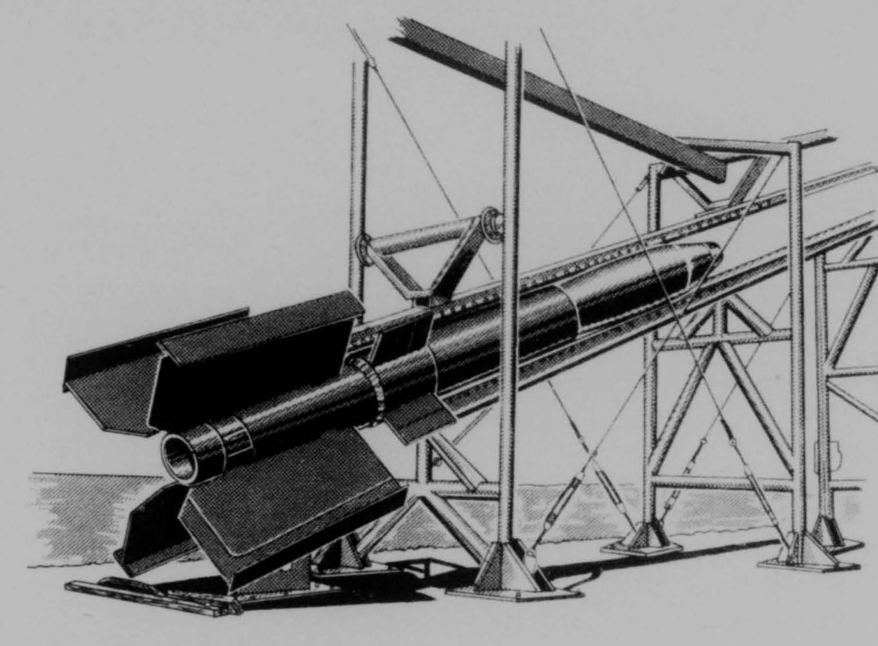


Figure 9–4. A Ram Jet on its Launching Ramp with Rocket Booster Attached

Jet engines are more simple and easy to maintain than the conventional reciprocating engine. Fuel consumption in jet engines varies from very high to low, in most cases it is quite high relative to the reciprocating engine, depending upon the altitude. At high altitudes a jet engine is more efficient on a gallon of fuel per milage basis than it is at low altitude. For example, doubling the fuel capacity of the F-80, with the addition of wing tip tanks, does not merely double the range, but triples the range. This is true because after the plane once reaches operational altitudes (30,000 feet or more), it then proceeds at much increased efficiency.

Also a jet engine may burn all types of fuel from 100-octane aviation gasoline to kerosene and even coal dust or paraffin. However, most jet engines are built to burn a certain fuel, principally kerosene; each type of fuel requires a special nozzle because the spray pattern in the combustion chamber is important.

Ram Jet

The ram jet is the jet propulsion engine which is most applicable to guided missiles. The gas turbine, either with a propeller turbo-prop or simply as a turbojet, may be very useful in missiles designed for speed from 600 to 1000 miles per hour. The German V-1 missile and several American prototypes made use of the pulse jet (intermittent or reed jet) as power plants. This type of jet motor is limited to subsonic speeds by its pulsating mechanism. Other types of jet-propulsion methods, such as the use of the exhaust gases of a conventional reciprocating engine to provide additional thrust, or the use of ducted fans with an axial flow jet engine, probably will not be used with guided missiles.

The reasons that the ram jet propulsion unit has a promising future in guided missiles

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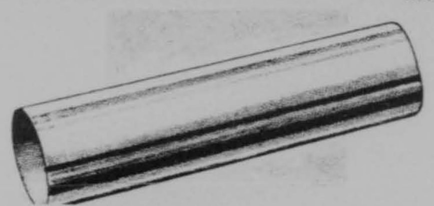


Figure 9—5. Ram-Jet Operation—Combustion in an Open Pipe. At Rest.

are: it is capable of high speeds, it is simple and cheap to construct, and at high speeds and high altitudes it is very efficient.

The main disadvantage to the ram jet is: it does not operate below 400-500 miles per hour, thus its initial operating speed must be obtained by rocket boost or some other auxiliary force.

The ram jet is so simple in construction that it has been called the "flying stovepipe." In order to explain how it functions the four following diagrams and explanations are given:

In Figure 9-5 the stovepipe is standing still, open at each end. The fuel is ignited at point A and the hot (expanded) gas escapes at each end of the pipe.

In Figure 9-6 the stovepipe is now moving forward (to the left) at 400 miles per hour, therefore, rammed air is travelling through the duct at 400 miles per hour without combustion. Now, when the heat of fuel combustion is added at point A, the expanding gas at A seeks to escape in all directions. It is opposed by the walls of the pipe, and in addition it is now opposed by the "head" of air at the front of the pipe. This means that the only means of escape is to the rear. The pressure heat produced by combustion is great and the gas has expanded so much that now it leaves the rear opening at 1400 mph. Thus the mass of air entering at the front is rapidly accelerated to produce thrust.

In actual operation the ram jet has a divergent nozzle in front. This nozzle raises the pressure of the air while decreasing its velocity inside the "pipe" and allows more heat to be added. Also the discharge nozzle is convergent, which increases the velocity of the issuing jet stream. Now as the ram jet goes faster the entry "head" is greater. This cuts

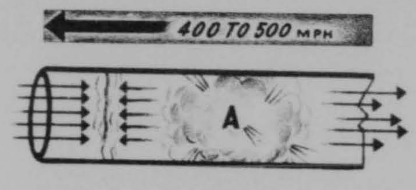


Figure 9—6. Ram-Jet Operation—Moving at 400-500 MPH. There is a Head of Air in the Front of the Pipe Which Resists Expansion (Acceleration) in That Direction.

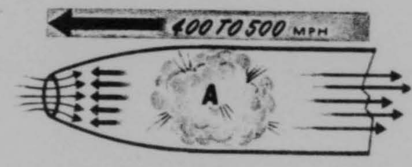


Figure 9—7. Ram-Jet Operation—Divergent Entry Nozzle Orifice Raises the Pressure of the Air "Head."

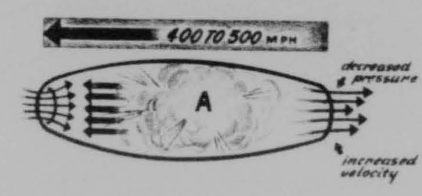


Figure 9—8. Ram-Jet Operation—A Convergent Discharge Nozzle Increases the Velocity of the Air Leaving the Engine.

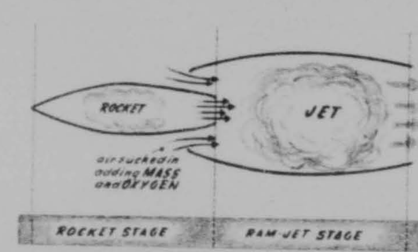


Figure 9—9. Rocket Ram-Jet Combination.

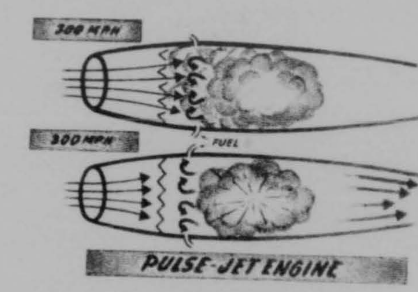
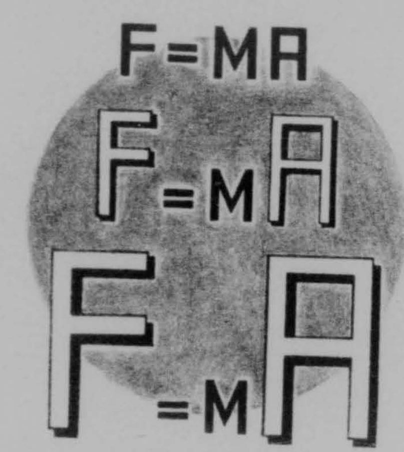


Figure 9—10. Pulse-Jet Engine.

down on the escape of gas to the front and adds to the velocity of the jet stream. Again the ram jet goes faster; the "head" is greater; and the acceleration is greater. Thus the ram jet lives up to its reputation—"The faster it goes: the faster it goes!" All because F—MA.

Where does this end? What is the limit? The answer is truly amazing. First of all, the ram jet must be launched by some thrust other than its own. To launch it requires an abundance of fuel (probably rocket propellent). Next, at low speeds ("low" for a ram jet—500 to 800 mph) the ram jet uses fuel rapidly. However, as it reaches extremely high speeds at very high altitudes the unbelievable happens. The ram jet unit itself gets so hot from "skin-friction" (atmospheric friction on a high velocity body, i.e., meteorites) that this heat provides heat for expansion of the air and little fuel is required. So now we find that the fuel-hungry jet has proven itself to be highly efficient.

There is a limit to this, however, for at this very high speed the temperature of skin friction is so high that the ram jet operates at white heat and soon collapses. In order to benefit from this potential advantage of the ram jet, research will have to create metals which will withstand these extreme temperatures. Despite the magnitude of this task there is hope that it will be achieved. A rocket-ram jet combination, first proposed by a French inventor in 1922, may develop into a very successful power unit for very high speed missiles. This combination would save propel-



lent in getting the missile out of the atmosphere, or would greatly increase range in the atmosphere.

Pulse Jet

All other jet propulsion engines suffer in comparison with the ram jet for simplicity and performance. However, the V-1 bombs made the world realize that the pulse-jet engine is an excellent propulsion unit. This engine can also be compared to a stovepipe, with the addition of shutters.

This pulse jet has a convergent nozzle in front similar to the one used on the ram jet. It also has tailpipe nozzle. The principal difference is the addition of the shutters between the front nozzle and the point of combustion. These shutters are spring-steel wedges, the tips of which touch each other when no air is entering between them. To start the pulse jet, compressed air is forced between these shutters and fuel is added to the combustion chamber. The fuel and air mixture is then ignited. When the expanding gases force against the wedges from the rear, the wedges close and the gases must be ejected through the tail nozzle. As the gases are exhausted the momentum of the exhausting gases lowers the pressure in the chamber, thus allowing a fresh charge of air to enter and the cycle repeats. In flight the incoming

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air forces its way between the shutters at about 2,800 cycles per minute. It was this intermittent cycle which made the buzzing sound that gave these bombs the name "Buzz Bombs."

Because of this intermittent burning and the shutter system the pulse jet does not exceed the speed of sound. As a propulsion unit for guided missiles it has its uses, but in the future, with speed being the element in demand it will not be able to compete with the ram jet and the rocket.

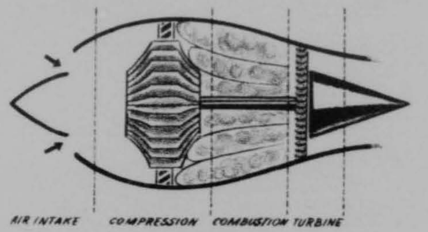
Gas Turbine

The gas turbine is also a jet-propulsion unit of great thrust potential, but at the present time a study of this engine is perhaps better suited to the Aeronautics section, because this engine is presently used predominantly in aircraft units. It can be well adapted to guided missiles; and several specially designed units are being used.

5. NUCLEAR POWER

The Nuclear Energy for the Propulsion of Aircraft (NEPA) Project is one of the most ambitious of the many projects supported by the Air Force. The contract for this project has been assigned to the Fairchild Engine and Airplane Corporation with the cooperation of the aircraft industry and the nation's atomic scientists. The utilization of atomic energy for aircraft or guided missile propulsion is considered to be predominantly an engineering problem rather than a problem of new scientific discovery.

One of the main advantages in the use of atomic power is that it provides an almost inexhaustible "fuel" or heat source. This, in a field that is especially handicapped by high fuel-consumption problems, is most important. In any missile propelled by nuclear energy the fuel supply would remain nearly constant. Enough fuel to start the reaction would



TURBO-JET ENGINE

be sufficient for sustained operation. However some "mass" would have to be carried for this nuclear fuel to accelerate.

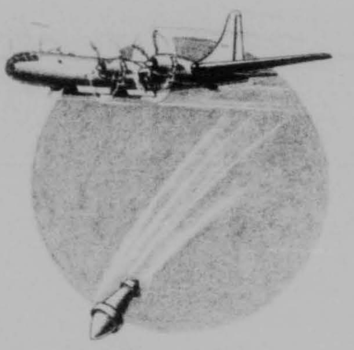
A major problem confronting the engineers is that which is concerned with protecting the crew and instruments from radiation damage. Of course, in a guided missile there is no crew to be considered, but a considerable amount of shielding would be necessary for the mechanism and instruments of the missile. Shielding is required to stop the radiation originating within the reactor, or chain-reacting system which it uses for power purposes. The stopping of electrons is no problem but the stopping of gamma rays and neutrons requires large masses of material. "Canning" the uranium block in the reactor is necessary to prevent the escape of violently radio-active fission fragments beyond the protection of the reactor shield.

When nuclear energy is adapted to missile power plants it probably will be in these types: steam or mercury turbine; turbo jets or gas turbines; ram jets; and rockets.

To date any such development would require a missile the size of the B-36. It will take many years of extensive technical development before nuclear energy is harnessed for missile propulsion. However, the outlook is promising, and the use of atomic energy will certainly make distance a minor factor in missile travel because of the large quantities of power it will develop.

SECTION VI—LAUNCHING METHODS

Because most guided missiles are designed for supersonic flight, the problems of launching these missiles are in most cases quite complicated. In order to study the various means employed, the classification of launching methods will follow the same general outline as assigned to the missiles themselves, i.e., air launched, surface launched and underwater launched.



TARZON

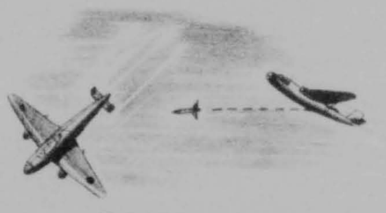
1. AIR LAUNCHED

Gravity

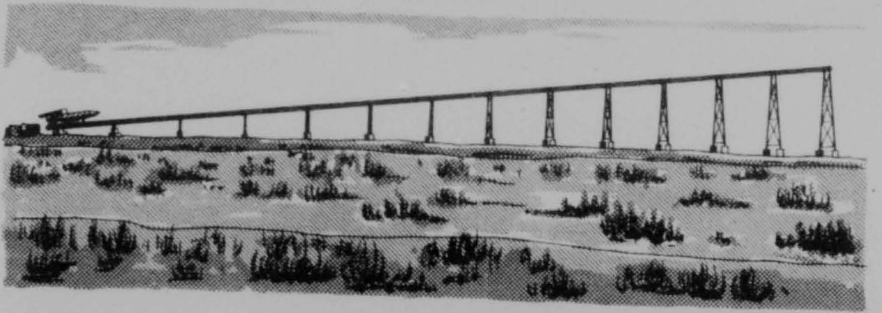
In this case the missile is dropped from the aircraft as a bomb. No further aid is applied during launching. The AZON and RAZON bombs, and the various glide bombs come under this category.

Rocket or Jet Propulsion

This missile carried by the launching aircraft is brought to the desired altitude and air speed. At the time of launching, the missile is accelerated by additional rocket charges. It is currently launched from under the wing or fuselage of the carrier aircraft.



JB-3 AIR-TO-AIR MISSLE



INCLINED LAUNCHING RAMP

Because of the drag on the carrier aircraft which is induced by the launching equipment (guide rails, brackets, etc.), the carrying aircraft is limited in speed. However, new methods are being considered whereby the missile may be carried partly, or completely, within the carrier aircraft.

2. SURFACE LAUNCHED

Gun

In the event an operational guided missile is developed which will operate inside the artillery shell, the missile will be launched from the gun which normally fires this type of shell. The actual launching will be the result of the combustion of the powder in the weapon the same as in the case of any shell being fired from a gun.

Runway

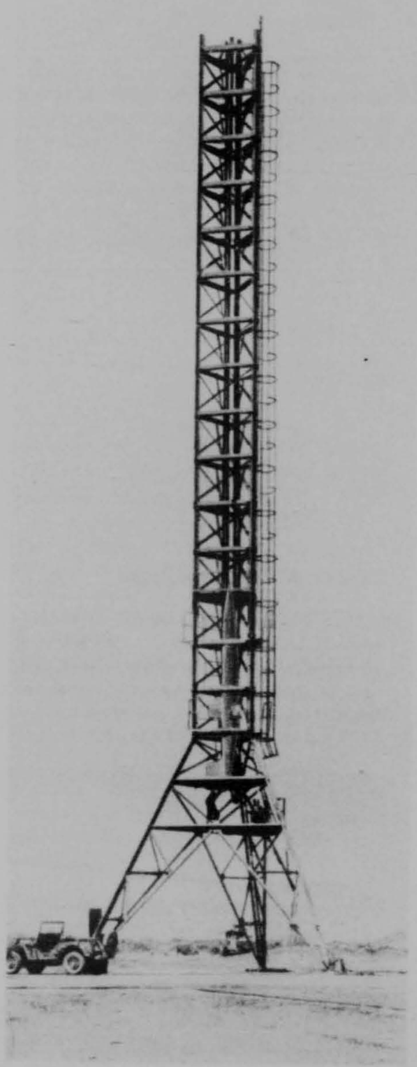
Guided missiles which are similar to conventional aircraft utilize runways for takeoff. They are launched under their own power. The system is subject to certain limitations in that jet- or rocket-propelled guided missiles will not operate efficiently at sea level, and much valuable fuel weight will be expended if this system is required.

Catapult

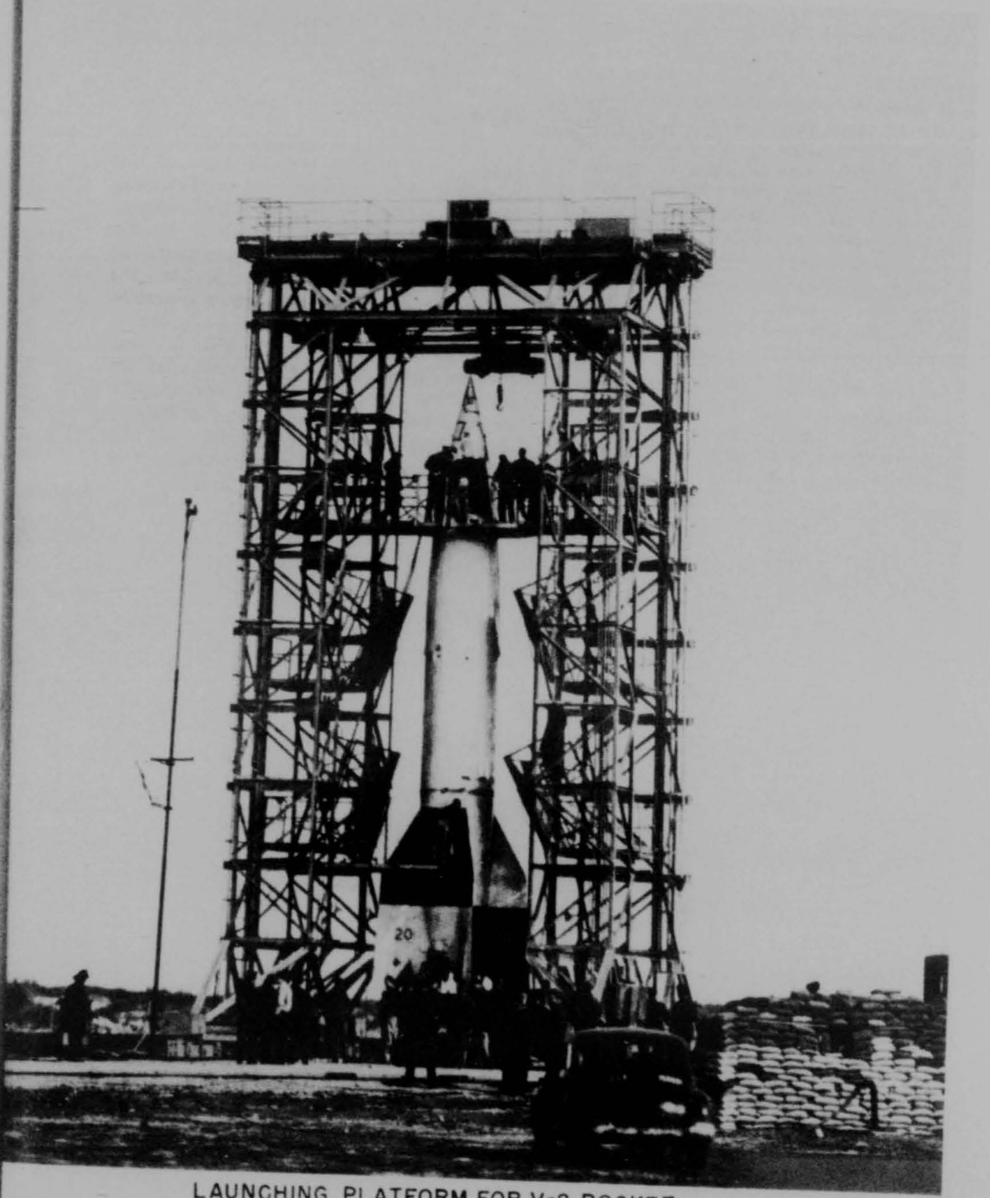
Naval aircraft have been launched successfully from catapults for years. These catapults have been powered by steam, electricity, compressed air, and other mechanical means. Powerful new catapults have been successfully used to launch guided missiles. Catapults are subject to the same limitations which curtail the use of runways for guided missiles. However, they do have the added advantage of providing rapid acceleration in a small distance, and in the case of naval vessels they enable the ship to launch guided missiles without a flight deck.

Ramp

The ramp combines features of the runway and catapult, being especially constructed for use in launching guided missiles. There are two general types.



VERTICAL LAUNCHING RAMP



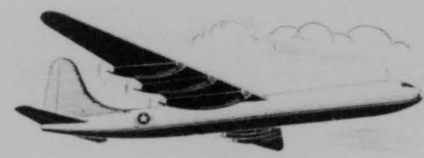
LAUNCHING PLATFORM FOR V-2 ROCKET

Inclined Ramp. This ramp is constructed to give lift to the guided missile as it takes off. The German V-1 was launched from a carefully prepared ramp which was built, aiming at the proposed target. The length of the ramp was determined by the amount of acceleration which was available to launch a given missile into self-sustaining flight. If the acceleration could be increased, the length of the ramp could be decreased. The limit would be either the amount of acceleration available, or the amount of acceleration the guided missile and its instruments could withstand. It is evident that the inclined launching ramp is an aiming device as well as a launching device.

Vertical Ramp. Some guided missiles are launched by means of a vertical ramp which supports the missile during the first part of its course. This type of ramp does not direct the guided missile to its target. Neither does it give it any increased acceleration. Its purpose is to help the missile during its initial vertical movement so that it will not topple or weave off course.

Platform

Vertical launching for high altitude, high-speed guided missile is the most practical. The missile is placed upright on a platform (cement base). Then by its own power it gradually accelerates vertically until it reaches high operational speed. During this method of launching, acceleration is kept low and the structural difficulties of high acceleration launching are avoided. Also, since a launching track is not necessary, the installation is simple and highly mobile. Furthermore, as the sonic flight velocity is passed very rapidly in an almost vertical trajectory, the difficulty of stabilization and control is minimized. For rocket propelled guided missiles this type of launching is perhaps the most feasible.



CONTINENTAL AIR COMMAND

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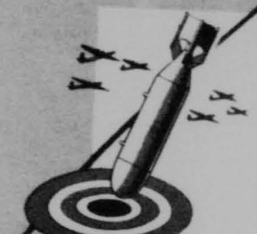
VOLUME III



AIR FORCE ROTC

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Foreword

HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK
8 June 1949

ConAC Manual 50-11 Vol. III is published for the information and guidance of all concerned. It will be used in conjunction with the current program of instruction pertaining to Air Force ROTC Training.

BY COMMAND OF LIEUTENANT GENERAL WHITEHEAD:

GORDON P. SAVILLE
Major General, United States Air Force
Vice Commander

HEADQUARTERS — OFFICIAL — CONTINENTAL AIR COMMAND

OFFICIAL:

NEAL J. O'BRIEN
Colonel, United States Air Force
Adjutant General

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THIS MANUAL SUPERSEDES ConAC Manual 50-140-1 Vols. I, II, III.

Preface

THIS textbook has been prepared specifically for the college or university student who is participating in the Air Force ROTC program. It is one volume of a series designed to qualify him as an officer specialist in the United States Air Force.

The text is planned to indoctrinate the officer candidate in the fundamental principles of Air Force Armament, rather than to present a detailed treatise of the entire complex field.

In order to achieve maximum efficiency and effectiveness in the performance of his duties, the Air Force officer must be constantly aware of new developments in his specialty and its allied fields. A receptive mind, nurtured by supplementary research and reading, can be a vital force in the personal and professional development of the officer specialist throughout his career.

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TABLE OF CONTENTS

CHAPTER 1—PRINCIPLES OF RADAR

SECTION I—ELEMENTS OF RADAR

1. GENERAL

Definition. Radar is an application of radio principles by means of which it is possible to detect the presence of objects, to determine their direction and range, and to recognize their character.

Principle. Detection is accomplished by directing a beam of radio-frequency energy over a region to be searched. When the beam strikes a reflecting object, energy is **reradiated.** A very small part of this reradiated energy is returned to the radar system. A sensitive receiver located near the transmitter can detect the echo signal and therefore the presence of the object or target. The determination of the actual range and direction is based on the facts that radio-frequency energy travels at the **constant velocity of light** and that the receiving system can be made directional.

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2. APPLICATIONS OF RADAR

Search

Tactical operations are based on the available knowledge of the enemy's dispositions and movements. Radar can be of extreme importance in providing a continuous flow of accurate information to the commanding officer. The initial location of the enemy and subsequent reports up to the time when action is finally joined is accomplished by search radar.

The problem of locating aircraft targets differs from that of locating surface targets in that the reflecting surface of an aircraft is small compared to that of a naval vessel. Also, since the speed of the aircraft is much greater, information is required at greater ranges in order to take effective action. This factor necessitates the use of early-warning radar for aircraft search. Such systems are intended to determine **range** and approximate **azimuth.**

The accurate-reporting systems permit the location of the target more accurately than do the early-warning systems. A means of measuring altitude is usually included in this type of equipment so that the target position is known in three dimensions. When the available data is used to direct fighter aircraft in the interception of the target, the name ground-controlled **interception** (GCI) is sometimes applied.

The location of surface craft involves the determination of only their range and azimuth. Surface-search radar is employed largely to provide the initial warning of the presence of such targets and to keep track of later movements. Since the speed of surface craft is relatively slow, exact data is not of great importance.

Fire Control

The problem of antiaircraft fire control requires accurate information on **range**, **azimuth**, and **elevation**. The maximum range of radar systems used for this purpose is limited to about 40,000 yards. The radar system is normally linked closely with the guns to be controlled because of the relatively short time during which an aircraft target is within firing range.

The problem of fire control against naval vessels is simpler from the standpoint of determining position and because of the much lower speed of the target. Fire-control systems for use against surface targets measure range and azimuth only, but to a high degree of accuracy. The data is used to compute the firing problem, and the results may be used by widely separated gun batteries.

Fire Control Air-to-Air. Radar is used in conjunction with remote-controlled turrets on aircraft. It provides two important functions: search and gun laying. The indicator of the radar set will present to the gunner information which indicates position and range of the attacking aircraft.

Airborne Use

One of the most important uses of radar is as an aid in the patrol of shipping lanes in search of enemy vessels. Aircraft-to-surface vessels (ASV) radar is able to increase the zone which can be searched by extending the range at which surface targets can be detected well beyond the visual limit. In addition, ASV provides an accurate means for guiding the patrol aircraft directly to the target.

Fighter aircraft can be directed to the general vicinity of the enemy planes by means of early-warning systems, but, unless conditions of visibility are adequate, they may completely miss the target. Aircraft-interception (AI) equipment in the fighter plane permits the crew to locate the enemy at short ranges and to close to the attack. The additional weight of the equipment and the need for an operator requires a special fighter aircraft known as the "night fighter."

Radar Bombing. Modern bombing attacks require that the presence and location of the target be known irrespective of atmospheric conditions and time of day. Radar has provided a source of such information. Bombing techniques involve the use of radar in several ways: (1) Radar sighting by observing the target on the scope. (2) Synchronous sighting with the radar set supplying the sighting information to the bombsight computer. In radar sighting, the slant-range, bomb-release

chart is used to determine the exact instant of bomb release. In synchronous sighting, a bomb-release chart is used to determine specific sighting angles from the plane to the target. The bombing methods just discussed are called direct bombing because they involve aiming directly at the target. However, this is not always practical for there are times when the target does not show up well on the radar scope. At such times, offset bombing is used. In this method, some object that shows up well on the scope and is near the target is taken as the aiming point, and the calculations are based around that point even though the bomb is still directed at the target.

Identification—Friend or Foe (IFF)

Although radar can locate an object such as an aircraft or vessel accurately, it cannot distinguish between friend and enemy. This inability is particularly dangerous in fire-control systems, since the firing may be completely blind much of the time.

Identification—friend or foe (IFF) equipment is used as an auxiliary to radar to identify friendly craft. The IFF system, located on the craft, receives from the radar location a challenging signal by radio means and returns a reply, either visually or by radio. IFF techniques are much the same as those of radar.

Navigational Aids

Radar is in itself a form of navigational equipment, since objects can be located with it. When the objects, such as mountains and prominent buildings, can be recognized, the movement of the vessel or aircraft can be guided accordingly.

Radar beacons are used to supplement the natural fixed targets which act as reference points. Beacons are similar to IFF systems in that they receive signals from the radar set and return other signals to it. Each installation has its own code to identify its location. Therefore, the use of beacons is an improvement over the use of fixed targets.

Radar altimeters are special radar systems used to measure the height above the surface of the earth. Such devices are called absolute altimeters because they measure the true distance to the earth without reference to sea level or barometric pressure. Since range is the only form of data required, and since the earth's surface is the target, altimeters are small and relatively simple.

3. RADAR METHODS

Continuous-wave (c-w) Method

One method of detecting a target makes use of the Doppler effect. When radio-frequency energy which is transmitted continuously strikes an object which moves toward or away from the source of energy, energy is reflected and its frequency is changed. The change in frequency is known as the "Doppler effect." A similar effect at audible frequencies is recognized readily when the pitch of the whistle of a train is heard as it approaches or leaves the listener. The radar application of this effect measures the difference in frequency between the transmitted and reflected energy to determine the presence and speed of the moving target. This method works well with fast-moving targets, but not with those which are slow or stationary. (C-W) systems are therefore limited in present usage.

Frequency-modulation Method

If the frequency of the transmitted energy is varied continuously and periodically over a specified band, the frequency of the energy being radiated by the antenna differs from that being received from the target. This difference occurs because of the time required for the energy to reach the target and return. The frequency difference depends on the distance traveled, and can be used as a measure of range. Moving targets produce a frequency shift in the returned signal because of the Doppler effect which affects the accuracy of range measurement.

Pulse-modulation Method

The radio-frequency energy can also be transmitted in short pulses whose time duration may vary from 1 to 50 microseconds (millionths of a second). If the transmitter is turned off before the reflected energy returns from the target, the receiver can distinguish

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between the transmitted pulse and the reflected pulse. After all reflections have returned, the transmitter can again be turned on and the process repeated. The receiver output is applied to an indicator which measures the time interval between the transmission of the energy and its return as a reflection. Since the energy travels at a constant velocity, the time interval becomes a measure of the distance traveled or range. Since this method does not depend on the relative frequency of the returned signal or on the motion of the target, difficulties experienced in the c-w and frequency-modulation methods are not present. The pulse-modulation method is used almost universally in military and naval applications. Therefore it is the only method discussed in this manual.

4. DETERMINATION OF RANGE

Time-range Relationship

The successful employment of pulse-modulated radar systems depends primarily on the ability to measure distance in terms of time. Radio-frequency energy, once it has been radiated into space, continues to travel with a constant velocity. When it strikes a reflecting object there is no loss in time, but merely a redirecting of the energy. Its velocity is that of light, or, in terms of distance traveled per unit of time, 186,000 land miles per second, 162,000 nautical miles per second, or 328 yards per microsecond.

The constant velocity of radio-frequency energy is applied in radar to determine range by measuring the time required for a pulse to travel to a target and return. For example, assume that a 1-microsecond pulse is transmitted toward an object which is 32,800 yards away. Figure 1-1 shows conditions at the instant the pulse is radiated. When the pulse reaches the target, it has traveled 32,800 yards at 328 yards per microsecond, and therefore 100 microseconds have elapsed. Figure 1-2 shows the pulse arriving at the target. The pulse is then reflected, and energy is returned over the same path. Since the return trip is also 32,800 yards, the required time of travel is again 100 microseconds. Figure 1-3 shows the pulse returned to the radar system. The

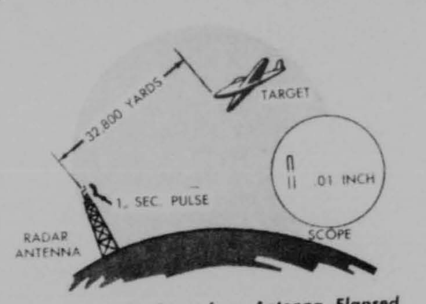

Figure 1—1. Pulse Starts from Antenna, Elapsed Time = O.

total elapsed time is 200 microseconds for a distance traveled of twice the actual range of the target. For radar ranging therefore, the velocity is considered to be one half of its true value, 200 × 164 = 32,800 yards.

Time Measurement

To employ the time-range relationship, the radar system must have a time-measuring device. In addition, since there may be more than one target in the region under search, some means of separating and identifying pulses must be included. The cathode-ray oscilloscope is well suited to such a task, since it retains the information on its screen and also forms a time scale. The time scale is provided by using a linear sweep to produce a known rate of motion of the electron beam across the screen of the cathode-ray tube.

The measurement of time is illustrated in the following example. Assume that a cathode-ray tube is used with a horizontal linear sweep which produces a beam whose velocity across the screen is 1 inch per 100 microseconds. The signals received from a target at a range of 32,800 yards are applied to the oscilloscope as a vertical deflection. Following the same sequence of operations as in the previous illustration, Figure 1-1 shows the radio-frequency pulse leaving the radar antenna and the sweep just starting across the screen. Since 1 microsecond has elapsed, the leading edge of the pulse has moved 328 yards from the antenna, and the sweep trace has moved 0.01 inch across the screen. The pulse is shown on the screen as a vertical deflection, since the receiver detects the pulse which is supplied

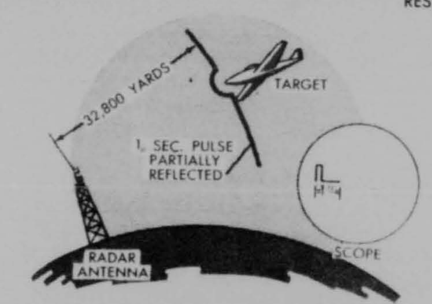

Figure 1—2. Pulse Reaches Target, Elapsed Time = 100 μ Seconds.

to the transmitting antenna. After 100 microseconds elapsed time the pulse reaches the target 32,800 yards away, and the sweep trace has moved 1 inch (Figure 1-2.) Since the pulse energy is out at the target, there is no deflection of the trace vertically. The reflected pulse returns to the radar antenna at the end of 200 microseconds, during which the sweep trace has moved a total distance of 2 inches. For the length of the received pulse (1 microsecond) the trace is deflected vertically Figure 1-3. Thus, with a constant sweep-trace velocity of 1 inch per 100 microseconds, a time scale is produced which is equivalent to 100 microseconds times 164 yards per microsecond equals 16,400 yards per inch of trace. If another target returned the transmitted pulse in 300 microseconds, the return signal would be indicated 3 inches from the start of the sweep, and the range of the target would be 300 × 164 = 49,200 yards.

The single-trace illustration used will not persist on the oscilloscope screen for sufficient time to be useful. Therefore, it is necessary to repeat the pulse transmission and the sweep trace periodically. If the two operations are made to start in the same time relation each time, signals returned from a given target will be superimposed on each other by successive sweep traces. The signals from all targets will be shown on the oscilloscope in their proper sweep-time-range positions (Figure 1-4).

5. DETERMINATION OF AZIMUTH OR BEARING

The measurement of the direction of a target from the radar system is usually given as

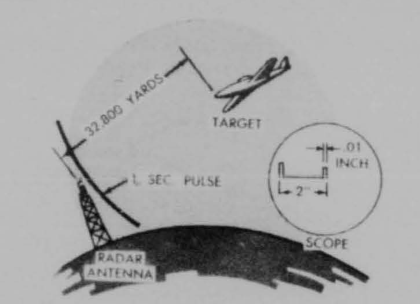

Figure 1—3. Pulse Returns to Radar, Elapsed Time = 200 μ Seconds.

an angular position. The angle may be measured from true north if the installation is stationary, or with respect to the heading of a vessel or aircraft containing the radar set. The angle at which the echo signal returns is measured by utilizing the directional characteristics of the radar antenna system.

The dimensions of the individual radiating element (the dipole) cause it to send out more energy in some directions than in others. When several elements are used togther to form an antenna system, the energy is further concentrated. Radar antennas are constructed of radiating elements, reflectors, and directors to produce a single, narrow beam of energy in one direction. The pattern produced in this manner permits the beaming of maximum energy in a desired direction.

The transmitting pattern of an antenna system is also its receiving pattern. An antenna can therefore be used to transmit energy, to receive reflected energy, or both.

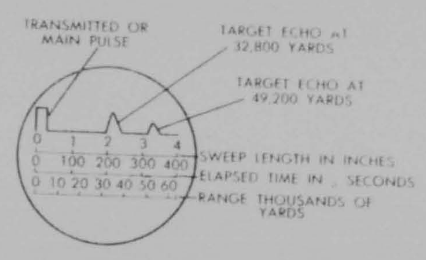

Figure 1—4. Range Indication of Several Targets.

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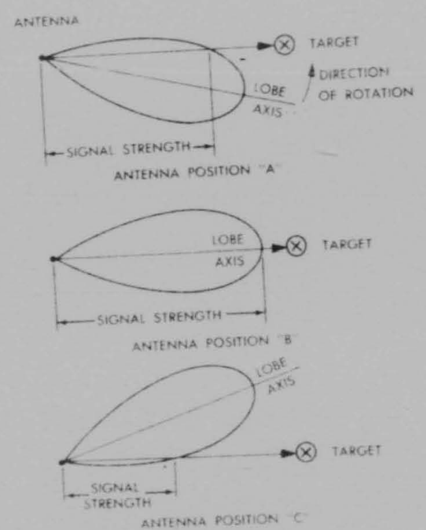

Figure 1—5. Relationship Between Beam Axis and Target Bearing.

Single-lobe System

The simplest form of antenna for meas- uring azimuth or bearing is one which pro- duces a single-lobe pattern. The system is mounted so that it can be rotated. Energy is directed across the region to be searched, and the beam is scanned in azimuth until a return signal is picked up. The position of the antenna is then adjusted to give maximum return signal.

Figure 1-5 shows the receiving pattern for a typical radar antenna. In it, relative signal strength is plotted against angular position of the antenna with respect to the target. A maximum signal is received only when the axis of the lobe passes through the target.

The sensitivity of the single-lobe system depends on the angular width of the lobe pattern. The operator adjusts the position of the antenna system for maximum received signal. If the signal strength changes rapidly with angular rotation, the accuracy with which the on-target position can be selected is great. Thus, in Figure 1-5, the relative signal strengths "A" and "B" have very little difference. If the energy is concentrated into a narrower beam, the difference is greater and the accuracy better.

Double-lobe System

Figure 1-6A shows that the signal strength varies more rapidly on the side of the lobe than near the axis. The greatest rate of change of signal strength per degree of rotation occurs between the angles which gave 50 and 85 per cent of maximum. Radar systems designed for gun laying or fire control require the highest possible accuracy in measuring azimuth angles. Figure 1-6. The double-lobe system achieves this accuracy by using two lobes to form the antenna-system pattern.

The principle of the double-lobe system is illustrated by using two separate antennas whose lobe axes are displaced by some angular distance (Figure 1-6B). The two lobe patterns intersect at one point only, known as the crossover point, at which equal signals are produced by the two antennas for this particular azimuth. At all other positions of the array unequal signals are produced.

The use of two lobes instead of a single lobe greatly increases the accuracy of azimuth

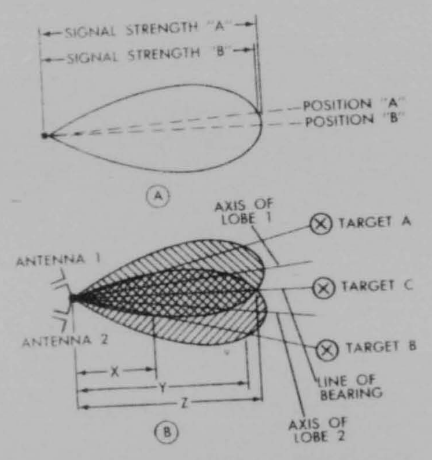

Figure 1—6. Single- and Double-Lobe Patterns.

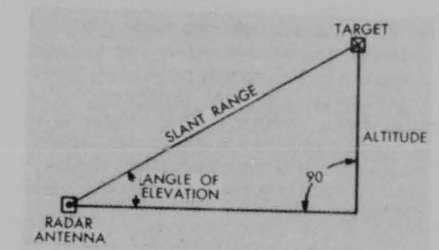

Figure 1—7. Determination of Altitude.

measurement. The amount of increase depends on the configuration of the antenna array. In general, the increase is at least five times, but it can be much greater. In addition to the greater accuracy of the double lobe, there is another advantage in the sense of direction available. If the antenna array is off-target on the side of lobe 1 the signal received by lobe 1 is the larger. Therefore the antenna should be rotated toward the left until the signals become equal.

6. DETERMINATION OF ELEVATION

The remaining dimension necessary to locate completely an object in space can be expressed either as an angle of elevation or as an altitude. If one is known, the other can be calculated from the right-triangle relationship and the slant range (Figure 1-7).

The free-space pattern of an antenna array is based on the arrangement of the individual elements within the system. If the same array is placed close to the earth, however, the vertical, free-space pattern may be changed by the effect of ground reflections. Figure 1-8A represents an antenna above the earth which has been elevated sufficiently so that energy will not strike the earth's surface and be reflected. Therefore the only energy that reaches the target is that which comes directly from the antenna system. If the antenna beam is lowered to the position shown in Figure 1-8B, some of the transmitted energy hits the earth and is reflected back into space. The target now receives energy from two directions and the effective field is the sum of the two fields so produced. The reflected wave travels farther than the direct ray in reaching the target. The addition of the fields at the target depends on the difference in the distance traveled expressed in wave-lengths. For example, if the path difference for a given target position is a half wavelength, the fields cancel. If the position of the target is changed so that the path difference is a full wavelength the fields add. The result of ground reflection is to break the single free-space lobe into a number of smaller lobes, with gaps between them.

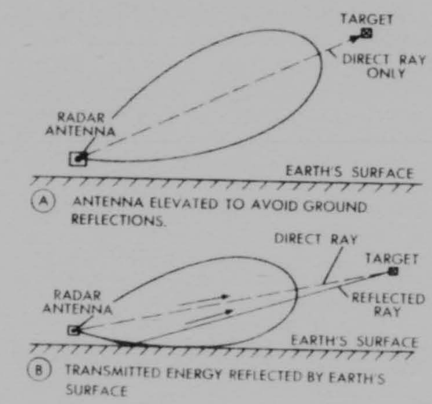

Figure 1—8. Elevation on Vertical Free-Space Pattern.

Methods

Any method used for determining the angle of elevation or the altitude must either make use of ground reflections or completely avoid them. The threshold-pickup method and the signal-comparison method use the effect of ground reflections to find altitude. The tilted-antenna method avoids ground reflections and measures the angle of elevation.

The threshold-pickup method makes use of the vertical-coverage pattern of an antenna system whose lobe axis is parallel to the earth. The positions of the lobes and gaps are determined by flying an aircraft toward the radar installation on known altitudes, and recording the ranges at which a minimum usable signal is returned. A typical plot of this data is shown in Figure 1-9. The chart obtained in this way is used by observing the range at which an unknown target first apears, and then reading its altitude from the chart. This method is very inaccurate, primarily because

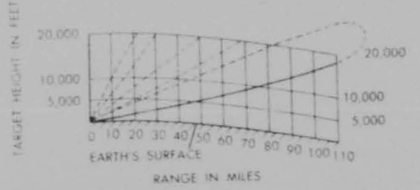

Figure 1–9. Calibration Chart for Estimating Aircraft Altitude.

the graph of the antenna pattern is determined by the use of a single aircraft while the target may be any number of planes. In general, the greater the number of planes, the greater is the strength of the returned signal. Therefore, a large flight of planes at a given altitude will be detected at a greater range than a single plane.

The signal-comparison method is simply an extension of the threshold-pickup method. Two antennas are placed one above the other to give slightly different vertical-coverage patterns. The lobes therefore overlap but do not coincide. The signals received on the two antennas are compared in magnitude, and their ratio, together with the range of the target, is applied to a height-range chart from which altitude is read. Under favorable conditions, the altitude can be determined within 500 feet.

The tilted-antenna method measures the angle of elevation directly in the same way that azimuth is measured. Ground reflections are avoided by using the system on targets which are high enough so that transmitted energy does not strike the ground. The accuracy of this method depends on the free-space pattern and the ability of the operator to locate the on-target position of the antenna array. Double-lobe systems are commonly used to increase the precision with which the antenna is pointed.

SECTION II—FUNCTIONAL COMPONENTS OF RADAR SYSTEM

1. FUNDAMENTAL ELEMENTS

Radar systems now in existence vary greatly as to detail. They may be very simple, or, if more accurate data are required, they may be highly refined. The principles of operation, however, are essentially the same for all systems. Thus a single basic radar system can be visualized in which the functional requirements hold equally well for all specific equipments. The varying details are due to a choice of specific circuits to fulfill these general functional requirements. In general, the degree of refinement of these circuits increases with the frequency, since the microwave region lends itself to a higher degree of precision in angular measurement.

Functional Block Diagram

The functional breakdown of the pulse-modulated radar system resolves itself into six essential components. These are shown in Figure 1-10 and may be summarized as follows:

The **timer** (variously known as the synchronizer, keyer, or control central) supplies the synchronizing signals which time the transmitted pulses and the indicator, and which coordinate other associated circuits.

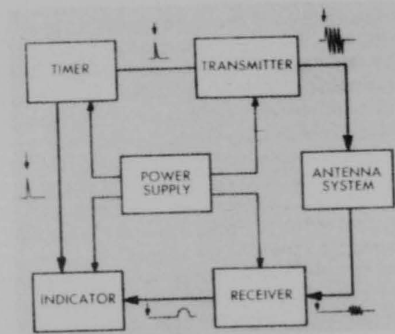

Figure 1–10. Functional Block Diagram of Fundamental Radar System.

The **transmitter** generates the r-f (radio frequency) energy in the form of short, powerful pulses.

The **antenna system** takes the r-f energy from the transmitter, radiates it in a highly directional beam, receives any returning echoes, and passes these echoes to the receiver.

The **receiver** amplifies the weak r-f pulses returned by the target and reproduces them as video pulses to be applied to the indicator.

The **indicator** produces a visual indication of the echo pulses in a manner which furnishes the required information.

The **power supply** furnishes all AC and DC voltages necessary for the operation of the system components.

Any radar system can be subdivided on the basis of the functional block diagram presented in Figure 1-10. An actual system may contain several functional components within one physical component, or a single function may be performed in several physical components. However, the analysis of the operation of a given set is greatly simplified by applying the functional block diagram without considering the physical location of the circuits.

2. SYSTEM CONSTANTS

Any radar system has associated with it certain constants. The choice of these constants for a particular system is determined by its tactical use, the accuracy required, the range to be covered, the practical physical size, and the problem of generating and receiving the signal.

Carrier Frequency

The carrier frequency is the frequency at which the radio energy is generated. The principal factors influencing the selection of the carrier frequency are the desired directivity and the generation and reception of r-f energy.

For the determination of direction and for the concentration of the transmitted energy so that a greater portion of it is useful, the antenna should be highly directive. The higher the carrier frequency, the shorter the wavelength and hence the smaller is the antenna array for a given sharpness of patterns, since the individual radiating element is normally a half-wave long. For an antenna array of a given physical size the pattern is sharper for a higher frequency.

The problem of generating and amplifying reasonable amounts of radio energy at extremely high frequencies is complicated by the physical construction of the tubes to be used. The common triode becomes impractical and must be replaced by tubes of special design. Among these are such types as the "lighthouse" triode, the grounded-grid triode, the klystron, the magnetron, and the "doorknob," "acorn," and "peanut" tubes. In general, the modifications are designed to reduce interelectrode capacitances, transit time, and stray inductance and capacitance in the tube leads.

The lowest carrier frequency normally used is 100 megacycles per second, in order to limit the antenna array to a practical size and yet to obtain the desired directional beam. Frequencies from 100 to 3,000 megacycles are in general use. Toward the upper end of this band, ranges are somewhat reduced because of inherent difficulties in generating and amplifying r-f energy at extremely high frequencies. Sets have been designed to operate up to and beyond 10,000 megacycles in order to produce very narrow beams or to reduce the antenna size.

Pulse-repetition Frequency

Sufficient time must be allowed between transmitted pulses for an echo to return from any target located within the maximum workable range of the system. Otherwise the reception of the echoes from the more distant targets will be obscured by succeeding transmitted pulses. This necessary time interval fixes the highest frequency which can be used for the pulse repetition.

When the antenna system is rotated at a constant speed, the beam of energy strikes a target for a relatively short time. During this time, a sufficient number of pulses of energy must be transmitted in order to return a signal which will produce a lasting indication on the oscilloscope screen. The persistence of the screen and the rotational speed of the antenna therefore determine the lowest repetition rate that can be used.

In a sytem in which the entire interval between transmitted pulses is used in the indicator, the repetition frequency must be very stable if accurate range measurement is desired. Since the oscilloscope screen will normally have a fairly long persistence, successive traces should appear in exactly the same position to avoid blurring.

Pulse Width

The minimum range at which a target can be detected is determined largely by the width of the transmitted pulse. If a target is so close to the transmitter that the echo is returned to the receiver before the transmitter is turned off, the reception of the echo obviously will be masked by the transmitted pulse.

Power Relation

A radar transmitter generates radio-frequency energy in the form of extremely short pulses and is then turned off between pulses for comparatively long intervals. The useful power of the transmitter is that contained in the radiated pulses and is termed the peak power of the system. Power is normally measured as an average value over a relatively long period of time. Since the radar transmitter is resting for a time which is long with respect to its operating time, the average power delivered during one cycle of operation is quite low compared to the peak power available during the pulse time.

A definite relationship exists between the average power dissipated over an extended period of time and the peak power developed during the pulse time. The time of one cycle of operation is the reciprocal of the repetition frequency, T = 1/f. Other factors remaining constant, the greater the pulse width the higher the average power; and the longer the pulse-repetition time the lower the average power. Thus:

$$\frac{\text{average power}}{\text{peak power}} = \frac{\text{pulse width}}{\text{pulse-repetition time}}$$

These general relationships are shown in Figure 1-11.

The operating cycle of the radar transmitter can be described in terms of the fraction of the total time that r-f (radio frequency) energy is radiated. This time relationship is called the duty cycle and may be represented as—

$$\frac{\text{pulse width}}{\text{pulse-repetition time}} = \text{duty cycle}$$

For example, a 2-microsecond pulse repeated at the rate of 500 times per second represents a duty cycle of 0.001, since the time for 1 cycle is 1/500 second, or 2,000 microseconds:

$$\frac{2}{2{,}000} = 0.001 \text{ duty cycle}$$

Likewise, the ratio between the average power and peak power may be expressed in terms of the duty cycle:

$$\frac{\text{average power}}{\text{peak power}} = \text{duty cycle}$$

In the above example it may be assumed that the peak power is 200 kilowatts. For 2 microseconds, then, 200 kilowatts of power are available, while for the remaining 1,998 microseconds zero power is available.

Since:

average power = peak power x duty cycle

Then

average power = 200 x 0.001 = 0.2 kilowatts

High-peak power is desirable to produce a strong echo over the maximum range of the equipment. Low-average power enables the transmitter tubes and circuit components to be made smaller and more compact. Thus it is advantageous to have a low-duty cycle. The peak power which can be developed is dependent upon the interrelation between peak and average power, pulse-width and pulse-repetition time, or duty cycle.

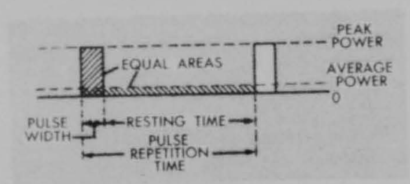

Figure 1—11. Relationship of Peak and Average Power.

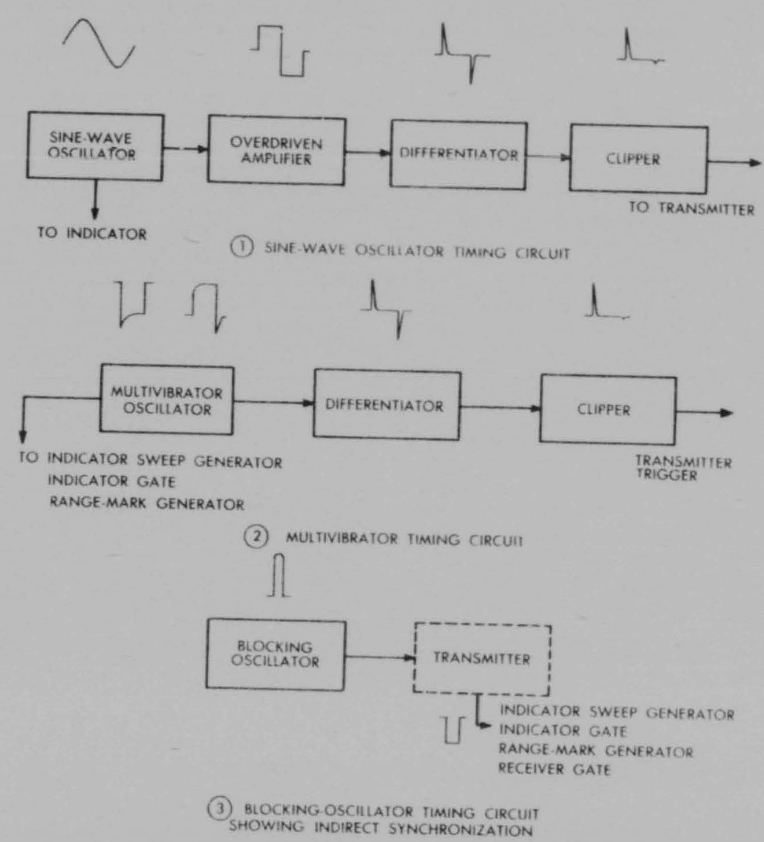

Figure 1—12. Representative Methods of Timing Radar Systems.

3. TIMER

The function of the timer is to insure that all circuits connected with the radar system operate in a definite time relationship with each other and that the interval between pulses is of the proper length. In general, there are two practical methods of supplying the timing requirements.

Timing by Separate Unit

The pulse-repetition frequency can be determined by an oscillator of any stable type such as a sine-wave oscillator, a multivibrator, or a blocking oscillator. The output is then applied to necessary pulse-shaping circuits to produce the required timing pulse. Figure 1-12 shows several typical combinations of circuits which may be used. The timing of associated components can be accomplished with the output of the timer or by obtaining a timing signal from the transmitter as it is turned on.

Timing Within Transmitter

The transmitter, with its associated cir-

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cuits, may establish its own pulse width and pulse-repetition frequency and provide the synchronizing pulse for the other components of the system. This action may be accomplished by a self-pulsing or blocking r-f oscillator with properly chosen circuit constants. This method of timing eliminates a number of special timing circuits, but the pulse-width or pulse-repetition frequency obtained may be less rigidly controlled than is desirable for some applications.

4. TRANSMITTER

Self-pulse System

In the self-pulsing radar transmitter the functions of transmitting and timing are carried out by one component. This type of transmitter, in effect, oscillates at two frequencies: the carrier frequency, as determined by the LC constants of the tank circuit, and the pulsing frequency, as determined by the RC constants of the grid circuit. The grid capacitor largely controls the width of the pulse in that its size determines the number of positive r-f swings required to charge it sufficiently to block the tube. The grid-leak resistor controls the pulse-repetition frequency to the extent that it determines the time required for sufficient charge to leak out of the grid capacitor to unblock the tube (the resting time). The timing pulse for other components is developed across a resistor in the cathode circuit of the blocking oscillator.

Externally-pulsed System

In the externally-pulsed type of radar transmitter the function of the r-f oscillator is relatively simple, that is, to generate powerful pulses of r-f energy at regular intervals. As the resting time is very long compared to the transmitting time, the oscillator may be greatly overloaded during transmission to increase the peak power. In this type of operation the r-f oscillator requires power in the form of a properly-timed, high-amplitude, rectangular pulse. In most cases the timing oscillator cannot fulfill this requirement directly, and therefore it is necessary to use a driver and a modulator. A driver is any circuit which, when triggered, drives the modulator with a rectangular pulse of accurately-timed width. A modulator is a circuit which supplies power to the r-f oscillator in the form of a timed, high-amplitude, rectangular pulse. The driver is triggered by the timer in order to maintain the repetition rate of the system. The driver, when triggered, shapes a rectangular pulse of proper time duration which in turn operates the modulator. The modulator then furnishes the high-plate voltage to the r-f oscillator for the predetermined pulsing time. Thus the transmitter function may be carried out by the combined performance of a driver, a modulator, and an r-f oscillator. The modulator acts like a power amplifier for the driver and like a switch for the r-f oscillator.

5. ANTENNA

The function of the antenna system is to take the energy from the transmitter, radiate it in a directional beam, pick up the returning echo, and pass it to the receiver with a minimum of losses. The antenna system may be considered to include the transmission lines from the transmitter to the antenna array, the antenna array itself, the transmission line from the antenna array to the receiver, and any antenna-switching device and receiver-protective device which may be present.

When a radar receiver is operated in close proximity to a powerful radar transmitter, a certain amount of signal inevitably finds its way into the receiver directly from the transmitter by way of the stray capacitance of the input circuit leads. In certain instances such signals resulting from the main transmitted pulse must be entirely eliminated from the output of the receiver. Therefore the receiver must be gated or turned off during the pulse time so that it may be completely insensitive.

It may be desirable to couple a small amount of the transmitted r-f energy to the receiver for timing purposes. However, the signal directly available from the transmission line is so strong that the receiver input circuit may be burned out. Because of the sensitivity of the receiver, the strong signal may also cause blocking of tubes which employ R-C grid circuits. This blocking occurs because

the strong signal will overdrive the tubes, causing grid current to flow which charges the capacitors. After the signal is removed the charge remains for some time as a bias which is much greater than cut-off. Both of these conditions place a limit on the permissible amount of transmitted pulse which can reach the receiver, and are the reasons for employing receiver-protective devices.

Use of Two Antennas

The simplest radar antenna system would contain two separate antenna arrays: one for transmitting and one for receiving. In this arrangement the receiving antenna must be shielded from the transmitting antenna to protect the receiver from the powerful pulses of energy being radiated. In general, the directivity of the antenna is sufficiently great to permit the location of the receiving antenna in a minimum signal region of the transmitting pattern. In aircraft installations the fuselage can be used to shield the receiving antenna from the transmitting antenna.

Use of Single Antenna and Switch

A more practical radar system employs a single antenna and an antenna switch capable of connecting the antenna to the transmitter during the transmission time and to the receiver during the remainder of the pulse cycle. The switch is necessary to protect the receiver from the transmitter during the pulse time and also to isolate the transmitter during the receiving time. Otherwise the weak echoes might be wholly or partially lost in following the transmission line back to the transmitter. The transmitted pulse width and the repetition frequency of the system, which may range from 60 to 4,000 cycles per second, eliminates the possibility of using a mechanical switch. Otherwise a double-pole, double-throw switch would serve the purpose.

A system for using the single antenna for both transmission and reception should be as efficient as possible. In other words, all of the energy produced by the transmitter should reach the antenna, and all of the energy should reach the receiver. This efficiency is most easily obtained by matching the antenna to the characteristic impedance of the transmission line. During transmission of the pulse, the transmitter should be matched to the transmission line and the receiver must present an open circuit or high impedance to the transmission line. During the reception time the conditions should be reversed.

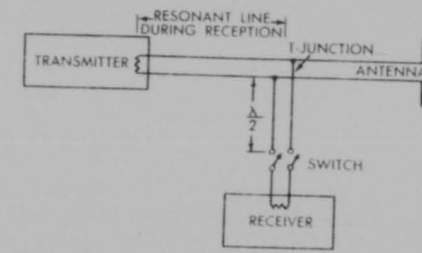

Figure 1—13. Elementary Switching System.

The problem of switching is usually simplified because most transmitters have a different output impedance when they are on than when they are off. If properly matched to the transmission line during the pulse, the transmitter will be mismatched for the receiving time, and the transmission line will become resonant. Figure 1-13 illustrates a typical elementary system in which the receiver and transmitter are connected by branch lines to the antenna feed line. The junction of the three lines is known as the T-junction. During the off period, the switch in the receiver branch is closed and the transmission line from antenna to receiver is properly matched. The resistance seen from the T-junction looking toward the transmitter can be controlled by the length of the resonant section between them. If the transmitter impedance decreases when it is turned off, the length should be a quarter-wavelength, or some odd multiple thereof, in order to see a high impedance. The high impedance presented by the transmitter and its feed line to the T-junction is in parallel with the relatively low-characteristic impedance of the remainder of the transmission line system, but, being high, has little effect. If the transmitter impedance increases when it is turned off, the resonant-line length should be a half-wavelength, or a multiple thereof.

When the transmitter is turned on to transmit the next pulse, it again will be properly matched to the antenna. The open switch (Figure 1-13) will prevent the pulse from reaching the receiver, and will cause a mismatch to the line between the switch and T-junction. By using some multiple of a half-wavelength, the open circuit of the switch will be presented as an open circuit across the transmitter-antenna line.

In a broad sense, then, the switching problem consists of providing what amounts to a double-pole, single-throw switch (Figure 1-13) for connecting the antenna alternately to the transmitter and to the receiver. The switching device must be capable of acting within a time interval of a few microseconds, as the receiever should be in the antenna circuit immediately after the transmission of the pulse in order to detect close-range targets. This microsecond timing requires that the device be electronic in type. Under various operational circumstances it may take the form of r-f amplifiers, klystrons, spark gaps, resonant transformers, spark-gap tubes, and (in waveguides) resonant slits. It is commonly known as the T-R (transmit-receive) switch or T-R box. Other terms frequently encountered are duplexer, reprod, and, in certain instances, polyplexer.

Types of Radiators

The principal types of radiators employed in the radar antenna system include: the stacked-dipole array with untuned reflector, the dipole with tuned reflectors and directors (Yagi), the dipole with parabolic reflector, and various arrangements of dielectric radiators used in conjunction with wave-guides.

A typical stacked-dipole array may be composed of one or more banks of dipoles and may be adapted for lobe switching. The entire assembly usually can be rotated in either azimuth or elevation, or both.

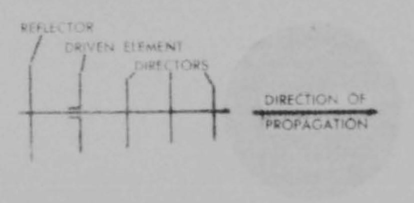

Figure 1–14. Yagi Array.

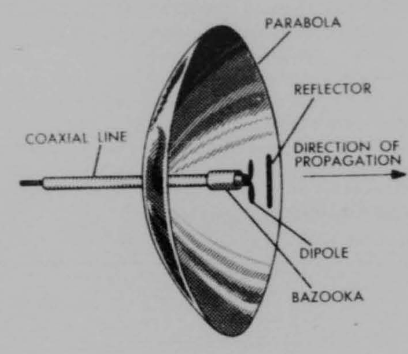

Figure 1–15. Dipole with Parabolic Reflector.

Figure 1-14 shows a type of Yagi array utilizing both director and reflector parasitic antennas in conjunction with a driven element. Only the driven element is connected to the transmission line. The other elements are excited parasitically, picking up energy from the driven element and reradiating it with such a phase relation with respect to the driven dipole that the field is reinforced in the forward direction.

Figure 1-15 shows the parabolic-reflector type of antenna, which is a practical means of producing a narrow beam pattern in the region of the micro-wavelengths. The reffection of r-f energy by the parabola or dish is closely analogous to the reflection of light by a parabolic mirror. The dish is large in comparison with the operating wavelength; in general, the larger the reflector, the narrower the beam pattern. The r-f energy is fed to a dipole located at the focal point of the parabola. A parasitic reflector is placed about one quarter-wavelength in front of the dipole, to reflect practically all of the radiated energy back to the dish from which it is reflected ahead in the form of a narrow beam. Modifications of this type of radiating system include cylindrical and other types of parabolas. Parabolic reflectors are frequently used in conjunction with wave-guides.

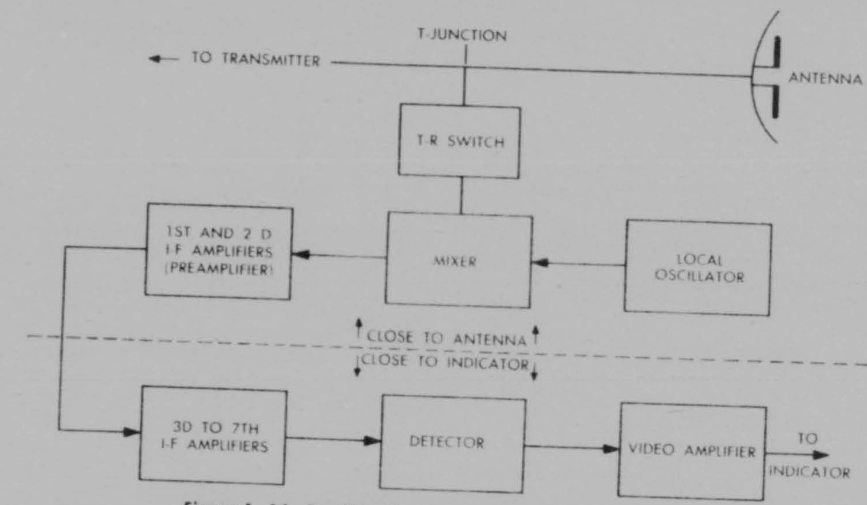

Figure 1–16. Possible Distribution of Receiver Components.

6. RECEIVER

The function of the receiver is to take the weak echoes from the antenna system, amplify them sufficiently, detect the pulse envelope, amplify the pulses, and feed them to the indicator. Since radar frequencies are high it is difficult to obtain sufficient amplification. Therefore, the receiver function of the radar system is performed by superheterodyne components of good stability and extreme sensitivity. The stability of operation is maintained in the microwave range of frequencies by careful design, and the over-all sensitivity of the receiver is greatly increased by the use of many intermediate-frequency stages. Special types of tubes having low interelectrode capacitances have also been developed for use in r-f, local-oscillator, and i-f stages.

Components

The r-f amplifier may not be present in the higher-frequency ranges and thus the received signal may be fed directly to the mixer. In this case, it is desirable to use as short a receiver-input transmission line as the design requirements allow. Thus, the mixer and local oscillator may be located close to the T-junction of the transmission line in order that the received r-f energy may be converted to the lower intermediate frequency before being relayed to the remaining receiver components. One or two stages of i-f amplification are sometimes located immediately after the mixer-local oscillator stage, functioning as a preamplifier to offset the considerable attenuation encountered in coupling the very weak received signal to the remote receiver components.

The components of the radar receiver may be distributed through the system in such a manner that their physical identity becomes lost. Figure 1-16 illustrates one representative distribution of the radar receiver components which makes it possible to locate the frequency-conversion portion in the immediate vicinity of the antenna and the video-amplifier portion in the vicinity of the indicator.

7. INDICATOR

The indicator uses the received signals to produce a visual indication of the desired information. The cathode-ray oscilloscope is an ideal instrument for the presentation of radar data since it not only shows a variation of a single quantity such as voltage, but gives an

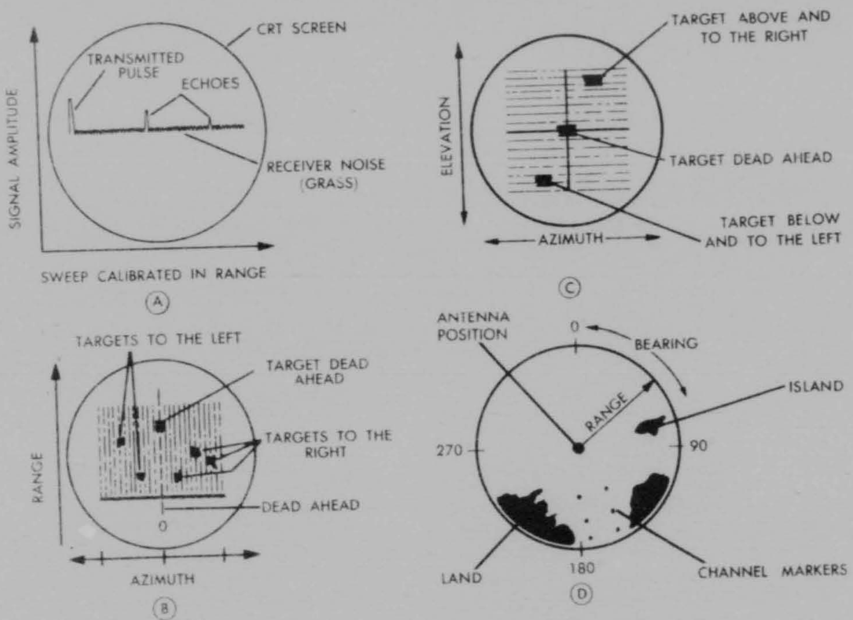

Figure 1–17. Types of Cathode Ray Oscilloscopes.

indication of the relative values of two or more synchronized variations. The usual indicator is basically the same in function as the low-frequency test oscilloscope. The focusing, intensity, and positioning controls are similar. The sweep frequency of the radar indicator is determined by the pulse-repetition frequency of the system and the sweep duration is established by the setting of the range-selector switch.

Types of Cathode-ray Oscilloscopes Used

The simpler systems of data presentation generally use the electrostatic cathode-ray tube in which the electron beam is made to follow some pattern by controlled differences in potential between pairs of deflecting plates.

The more highly-refined systems of data presentation generally utilize the electromagnetic cathode-ray tube with a long-persistence screen. The position of the electron beam at any instant is determined by causing it to pass through a magnetic field produced by controlled currents through deflecting coils mounted outside the tube. If intensity modulation is used, the bias is such that the tube is held just beyond cut-off, and the video output of the receiver is applied to either the grid or cathode with such polarity as to release the beam and allow the trace to appear on the screen. Thus the bright spots on the screen represent returning echoes detected by the radar receiver.

Type A-scan Presentation

The A-scan (Figure 1-17A) uses an electrostatic cathode-ray tube with a linear sweep applied to the horizontal deflecting plates to establish a time base, and with the video output of the receiver applied to the vertical deflecting plates. Since the sweep is linear with time, a scale which is calibrated in range may be placed on the oscilloscope screen. This scale permits the reading of range directly.

Since the antenna beam is highly directive, the maximum received echo appears when the antenna is pointing directly at the target. Thus, by rotating the antenna until the echo pulse produces maximum deflections on the screen, an indication of direction in azimuth or elevation can be obtained.

Type B-scan Presentation

The B-scan (Figure 1-17B) plots range against azimuth. Usually an electromagnetic tube is used. The sweep current flows through the vertical deflecting coils. A positioning current controlled by the antenna position flows through the horizontal deflecting coils, so that the position of the vertical sweep is aligned with the position in azimuth of the antenna, which may scan a region up to 90 degrees on either side of dead ahead. The return signals are used with an intensity-modulated scope to cause the target indications to appear on the screen.

Type C-scan Presentation

The C-scan (Figure 1-17C), developed primarily as a pilot's remote indicator, plots elevation against azimuth. The oscilloscope is intensity modulation by the echo signals. Modifications which present a means of estimating the range in addition to the indication of the elevation and bearing are more likely to be encountered than the basic type.

Type PPI-scan Presentation

The PPI-scan (Figure 1-17D) presents, in polar coordinates, a map of the area being covered with the antenna position occupying the center of the screen. The tube is intensity-modulated with the sweep moving from the center, radially outward. The sweep position is controlled by and synchronized with the antenna position throughout 360 degree rotation. The top of the screen represents dead ahead; if the antenna is pointing dead ahead, the sweep moves from the center of the screen to the top. Likewise, if the antenna points 90 degrees from dead ahead, the sweep moves from the center radially outward at an angle of 90 degrees to the right of dead ahead. Thus, a polar map is developed on which the range

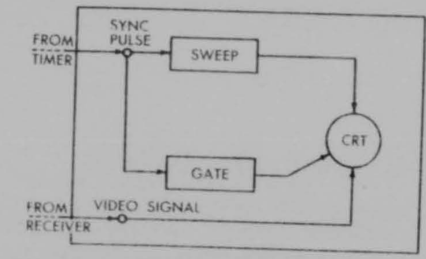

Figure 1–18. Basic Components of Radar Indicator.

is plotted radially against the position in azimuth, or bearing, through 360 degrees. The PPI-scan finds considerable application in equipments designed for search, harbor control, convoy keeping, ground-controlled interception, and navigation.

Components

The basic components of a radar indicator are a cathode-ray tube, a sweep circuit, and a gate circuit. These are illustrated in Figure 1-18. Various refinements may be added to improve the data presentation and to meet specific operational requirements.

In order that the data supplied by the indicator may be useful, the indicator's performance must be synchronized with that of the other components of the system. Thus, the start of the sweep must bear a definite time relation to the beginning of the transmitted pulse. The gating of the cathode-ray tube also must be timed with the sweep duration. Various methods of data presentation requiring sweep controls of varying degrees of complexity may be used.

8. POWER SUPPLY

Distribution

In the functional diagram of the radar system (Figure 1-10), the power supply is represented as a single block. Functionally, this block is representative; however, it is unlikely that any one power supply could meet all the power requirements of a radar set. The distribution of the physical components of the system may be such as to make it impractical

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to lump the power-supply circuits into a single physical unit. Thus, different supplies are needed to meet the varying requirements of the system and must be designed accordingly. The power-supply function is performed, therefore, by various types of supplies distributed among the circuit components of the radar equipment.

SECTION III—TIMERS

1. GENERAL

Introduction

Circuits which control and synchronize the operation of the various components of radar equipments are known as timers. The timing circuits are either assembled into a unit which constitutes a separate component of the equipment, or, as in the usual case, they are contained within one or more additional components, such as the indicator, the receiver, and control circuits.

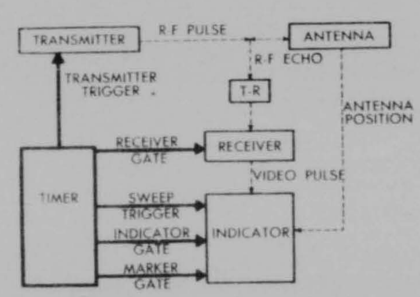
For the purposes of study, timers have been divided into two general types. One is the self-synchronized type in which the timing function is performed within the transmitter circuits. The other is the externally-synchronized type in which a master oscillator in the timer establishes the repetition rate and supplies trigger voltages for controlling the entire system.

Timing Signals

The signals required of the timing circuit depend largely upon the purpose of the set, the type of transmitter, and the method of data presentation. Typical requirements are illustrated in Figure 1-19. This diagram does not necessarily apply to any particular set, but shows the more common timing pulse channels in general use in many systems. In Figure 1-20 these timing pulses are shown in their proper time relationship.

Figure 1-20A represents the time-reference pulse originating in the timer circuit, and shows wave forms typical of the externally-synchronized systems. This figure is equally typical of self-synchronized systems in which the time-reference pulse is developed in the transmitter circuit. The time-reference pulse is used to trigger the various timing circuits into operation. Thus, in the former case, the pulse shown in Figure 1-20A becomes a transmitter trigger, and in the latter case it becomes a timer trigger. In either case, it serves as the reference point from which the other operations are timed.

The second timing pulse shown in Figure 1-20C gates the receiver to make it operative during only the proper portion of the pulse cycle. It may be necessary to gate the receiver in this way in some sets in which short minimum ranges are important. The T-R switch normally limits the amount of transmitter signal entering the receiver to a value which does not damage the crystal mixer, but it may not prevent blocking of the receiver circuits. When blocking occurs, the receiver remains inoperative for an interval immediately following the transmission of the pulse. This interval is required for recovery of the receiver to a state of normal sensitivity. If the plate and screen voltages of the first two or three i-f stages are removed during the transmitting time, receiver blocking is prevented and the minimum range at which targets can be detected becomes simply a function of the pulse width. The timing circuits are made to apply these screen and plate potentials in the form of a positive, rectangular gate voltage during the time interval beginning just after the end of the transmitted pulse and ending after echoes are received from the most distant targets in the operating range. Improvements in radar-receiver and T-R switch design have shortened recovery time to such an extent that, in many recent sets, it is unnecessary to gate the receiver.



*ESTABLISHES THE TIME REFERENCE FOR THE SYSTEM

Figure 1—19. Typical Pulses of a Radar Timer.

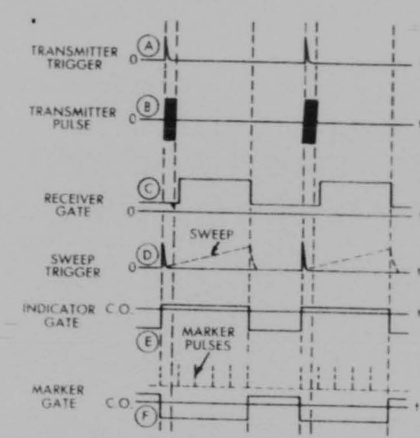


Figure 1—20. Time Relationship of Pulses Furnished by Timer Shown in Figure 1—19.

The timer starts the range sweep in the indicator circuits. The timing pulse may be in the form of a trigger as shown in Figure 1-20D, where it occurs simultaneously with the transmitted trigger, so that the beginning of the sweep and the beginning of the transmitter pulse coincide. If any appreciable delay occurs in starting the sweep in a cathode-ray tube which uses magnetic deflection, the sweep trigger may be made to precede the transmitter trigger to compensate for this inherent delay. The more commonly-encountered alternative, however, is to trigger the sweep coincidently with the transmitter and develop a trapezoidal sweep voltage to overcome the delay.

If the tube remains in an operating condition during the entire pulse period, both the forward sweep and the return trace will be visible, so that signals appearing on the screen from targets outside the desired range will cause confusion in interpretation of echoes. To avoid this, the circuits of the cathode-ray tube permit its operation to be controlled by a rectangular voltage, or gate. In Figure 1-20E this gate is shown to be positive during the sweep time and is applied to the grid of the cathode-ray tube to reduce the bias sufficiently to make it operative. At the end of the sweep time, the grid is returned to a high bias condition and signals returning during the remaining portion of the pulse period cannot appear on the oscilloscope. The same results are obtained by applying a negative gate to the cathode of the indicator tube during the sweep time.

The most commonly used method of estimating range directly on the indicator screen involves the production of range-marker pips in the indicator circuits and superimposing them on the video output of the receiver. The oscillatory circuit which generates the marker signals is gated by a rectangular pulse furnished by the timer, as shown in Figure 1-20F. The marker gate enables the marker circuits to operate during the sweep time only and may be either positive or negative, depending on the input requirement of the marker generator.

To provide the required timing pulses the timer must include the following:

A circuit capable of establishing the pulse-repetition frequency. This may be simply the grid circuit of an r-f blocking oscillator, a rotary spark-gap type of modulator, a sine wave oscillator, a multivibrator, or a single-swing blocking oscillator.

Means of forming the desired signals with the proper time relations. These may include such circuits as limiters, clampers, peakers, amplifiers, controlled multivibrators, and delay networks.

Circuits designed to protect one component from the loading effect of another and to deliver pulses to the loads without distortion, include the buffer amplifiers and cathode followers.

SECTION IV—TRANSMITTERS

1. GENERAL

Selection of R-F Generator

The selection of the r-f generator is governed chiefly by the carrier frequency at which the system is to operate. The carrier frequency depends on several factors, among which are the desired directivity of the antenna, the effect of frequency on propagation, and the tactical application of the system.

After determining the carrier frequency, the next step is to select the r-f generator. The triode oscillator is able to produce high peak power in pulse operation up to 400 megacycles per second. Because of interelectrode capacitances, electron transit time, lead inductances, and stray capacitances, the triode is incapable of producing a pulse of large peak power at higher frequencies. However, triode oscillators may be used to produce pulses of relatively low peak power at frequencies up to 600 megacycles per second. Such an r-f generator is useful in lightweight sets where high-power output is not essential. Above 600 megacycles, the magnetron is by far the most efficient r-f generator known at present, and is used almost exclusively in micro-wave radar. In a few cases a special form of triode, called the lighthouse triode, is used in low power transportable microwave radar sets.

Selection of Method of Pulsing

Three important pulsing methods are in use at present: self-pulsing in a triode blocking oscillator; production of a low-power pulse which is shaped and amplified to the proper magnitude to operate the r-f generator; and the production of a high-power pulse which is applied directly to the r-f generator. The method used depends on the type of r-f generator, the accuracy of range measurement to be obtained, and the minimum range desired.

The triode oscillator is pulsed equally well by all three of the above methods. The method which is used with a magnetron, however, must produce a rectangular pulse with very steep sides in order to apply a fairly constant voltage to the magnetron during the pulse time. Otherwise power is wasted by the production of oscillations of several different frequencies. Early pulsing systems for magnetrons were of the type that produced a low-power pulse and amplified it to the proper magnitude.

The limitation on the use of such pulse-amplifier systems is the amount of pulse power which can be produced without the use of many tubes in complicated circuits. This upper limit is about 200 kilowatts. The high-power pulse-generating systems use spark gaps capable of controlling enormous peak powers. Radar sets are now available which by using rotary gaps to extend the life of the system, produce r-f pulses of peak power exceeding a megawatt.

If extreme precision of range measurement is necessary, the leading edge of the transmitted pulse must be as steep as possible in order that the zero time for each sweep may be accurately determined. In applications where very short ranges must be measured—for example, in aircraft interception—the transmitted pulse must be short and the trailing edge of the pulse must be very steep. This is necessary so that the change-over from the transmitting condition to the receiving condition may be made as rapidly as possible to avoid masking of nearby targets. The self-pulsing triode oscillator does not meet either of these requirements well enough to permit its use in precise range-measuring systems. However, because of its simplicity, this type of pulsing is of considerable value in search systems where a high degree of accuracy and measurement of very short ranges are not required.

2. R-F GENERATORS

Triode Oscillators

Although triode tubes may be operated with their control grids positive to produce very

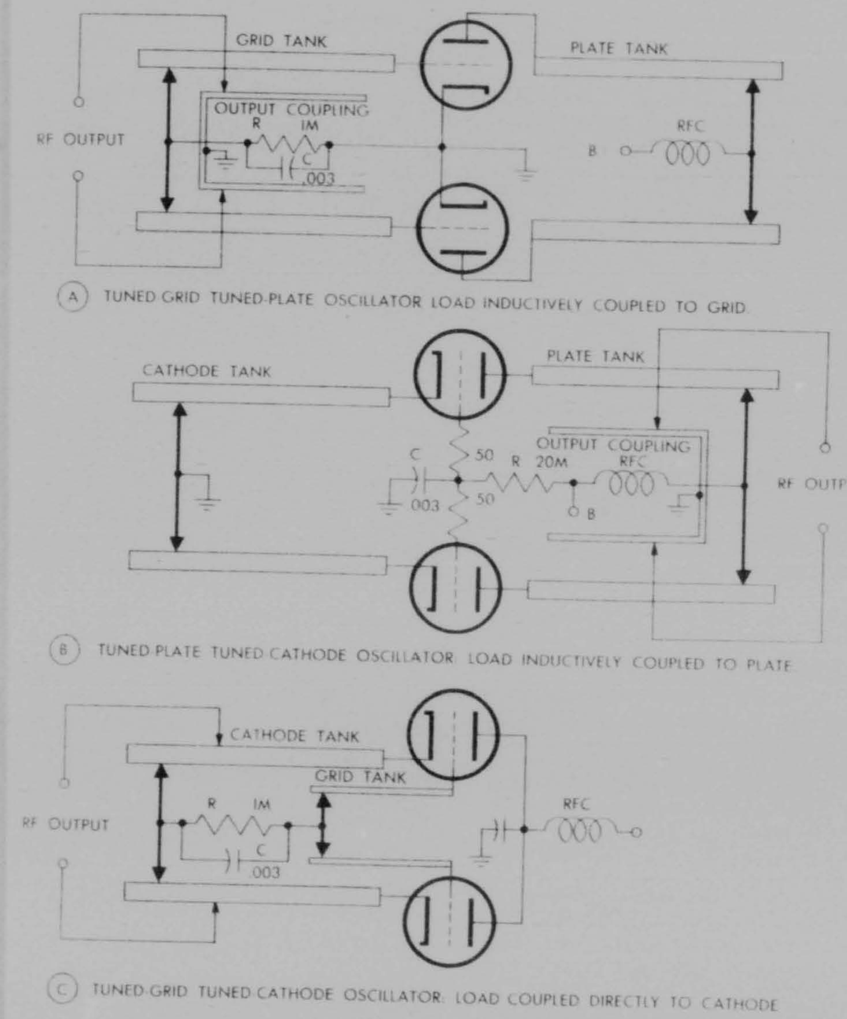


Figure 1—21. Representative Circuits of Push-Pull Oscillators.

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high frequency oscillations, as in the Barkhausen-Kurz oscillator, such circuits are not used in radar transmitters because they are too inefficient to supply the high peak power necessary. The triode oscillators which are used are of the negative-grid type, connected in a two-tube, push-pull circuit.

The tuned circuits used in triode radar-transmitter circuits are usually short-circuited quarter-wave sections of two-wire transmission line. These tuned circuits may be connected in the oscillator circuit in any of the ways shown in Figure 1-21. Oscillations are produced by feed-back through interelectrode capacitances. Other connections may be used, particularly when the length of the filament leads within the tube is such that special precautions must be taken to eliminate degeneration in the cathode circuit and the feedback of r-f energy into the power line.

All oscillators shown are self-pulsed. In "B", the grid is connected to B through a high resistance in order to establish a slightly more stable pulse-repetition frequency than is possible with the connections shown in "A", or "C". In all cases the flow of grid current charges capacitor C to produce a bias large enough to stop oscillation. A reduction in the size of the grid-leak resistor or an increase in the size of the capacitor will prevent self-blocking; all types may then be pulsed by common forms of modulators.

Energy may be coupled out of the oscillator inductively, capacitively, or by direct connection. Capacitive coupling is seldom used alone, but it may be used in conjunction with inductive coupling. Inductive coupling to the grid circuit is used in some radar transmitters, but usually this type of coupling reduces the Q of the grid tank circuit so much that it cannot be used to control the frequency of the oscillator effectively. One important difficulty that arises from inductive coupling to the plate tank circuit (Figure 1-21B) is that the voltage between the coupling line and the plate-tank circuit is the sum of the DC voltage and the r-f voltage. Because of this large voltage, the coupling line cannot be moved too close to the plate tank because in some cases flat optimum coupling cannot be obtained. This difficulty is overcome in the direct coupling arrangement shown in Figure 1-21C. There is no DC voltage on the cathode; therefore, the transmission line may be coupled to the cathode tank to any desired degree by adjusting the position of the output tap.

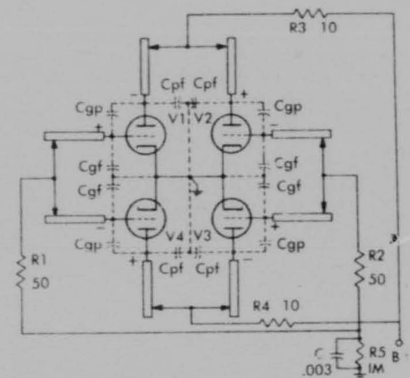

Figure 1-22. Diagram of Tuned-Grid Tuned-Plate Ring Oscillator.

Ring Oscillator

The power output of a two-tube, push-pull oscillator is limited by the peak plate current that can flow in the tubes and the power dissipation of the plate. To increase the power output it is necessary to increase the current-carrying capacity of the tubes, or to increase the number of tubes in the circuit. Because of electron transit time, interelectrode capacitance, and lead inductance, it is undesirable to increase the physical size of the tube to provide greater current-carrying capacity. Although increasing the temperature of the filament will permit greater emission, this change greatly shortens the life of the tube. Increasing the number of tubes by paralleling allows a higher peak power to be generated, but it also increases the effect of the interelectrode capacitances. When it is necessary to build an oscillator of high power, tubes are added in pairs in series to form a ring circuit (Figure 1-22).

The ring oscillator shown is an extension of the oscillator of Figure 1-21A. The effect of the interelectrode capacitances in this type of circuit is half of that for the same tubes connected in a push-pull parallel circuit. Addition of tubes in series to form a ring, therefore, permits a given type of the tube to be used at a higher frequency or allows the use of tubes which are physically large.

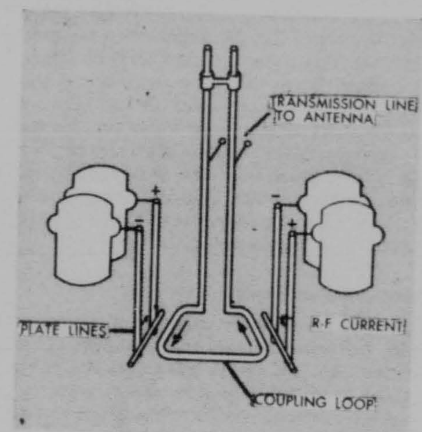

Figure 1—23. Coupling in a Ring Oscillator.

The ring oscillator functions because of the feedback of energy from plate to grid through interelectrode capacitances, and because of the voltage distribution on the plate and grid lines. Proper adjustment of the tank circuits causes a regenerative voltage to be fed back through the grid-plate capacitance. At the same time standing waves of voltage are established on the sections of transmission lines which cause the voltage at one end of the line to be out of phase with the voltage at the other end. Assume that the grid signal of VI (Figure 1-22) is positive at a given instant. The plate signal of VI will be at a minimum or negative maximum. The plate of V2, approximately a half-wavelength away, is positive because of the standing wave of voltage on the tuned transmission line. The signal on the grid of V2 is produced by interelectrode capacitance as a negative maximum, in order to reinforce the plate current. Continuing around the ring in this manner, the grid of V4 is at a negative maximum to close properly with the grid VI, a half-wavelength away. Plate relations are maintained by always adding tubes in pairs, if a larger number is needed.

The physical construction of the ring oscillator normally is arranged to have the tubes placed in an approximate circle with the tank circuits on the inside of the circle. This arrangement permits symmetrical connections between circuit elements, and allows the output coupling to the transmission line to be relatively simple construction. Figure 1-23 shows one method for obtaining energy from the tank circuits. The plate lines are supported vertically between the tubes, with the shorting bars at the lower ends. The polarity of voltage at the plates is as indicated and this causes the currents in the shorting bars to have the relative direction of flow shown by the arrows. A transmission line with a loop in the end is lowered between the plate lines so as to place the loop near the shorting bars, to provide inductive coupling. The magnetic fields produced by the currents in the shorting bars reinforce each other in inducting the r-f voltage in the loop. The line and loop can be made resonant by using a shorting bar a half-wavelength from the loop to insure maximum transfer of energy. The feed line is tapped across the resonant section in this case.

Any of the push-pull oscillators shown in Figure 1-21 may be connected in a ring circuit to produce a high-peak power output. Since the ring connection reduces the effect of the interelectrode capacitance, tubes of fairly large physical size may be used to produce high-peak output power at frequencies up to 400 megacycles. To produce even greater peak-output power than is possible with the four-tube ring oscillator, additional tubes may be added in pairs to the circuit.

The ring oscillator has the disadvantage of having many tuning adjustments in its circuit. If the several adjustments are not made properly, inefficiency will result. Because the ring circuit permits mechanical symmetry in construction, the tuning adjustments may be ganged to a few controls, and the oscillator is relatively simple to operate.

Magnetron

The magnetron is used as an r-f generator at frequencies above 600 megacycles per second. Since statement of the frequency in this range may involve rather large numbers, magnetrons are usually described in terms of the wavelength of the r-f energy they produce. The general range of wavelengths in which magnetrons are practical is called the microwave region. For use in this region, magnetrons have been manufactured which are capable of producing peak output as high as a megawatt. The efficiency of the magnetron as a device for converting DC energy to radio frequency energy is approximately 30 to 50 per cent.

Magnetrons for radar use require high plate voltages to cause oscillation. During the oscillating period, the current drawn is 10 amperes or more. The effective impedance of the magnetron while it is oscillating is approximately 1,000 ohms. Although it is desirable to reduce the magnetron impedance to a low value to eliminate the necessity for extremely high plate voltage, it has been impossible to reduce the effective plate impedance below approximately 500 ohms, even by special design.

It is characteristic of the magnetron that, if the plate voltage falls very greatly during the pulse, modes of oscillation other than the one desired may result. Oscillation in this manner causes serious loss of power, lowered magnetron efficiency, and difficulties in tuning the system, since unwanted frequency components are produced in the output. Therefore, the voltage applied to the magnetron must rise to the full value as soon as possible and remain constant during the pulse, and decrease to zero in a short time at the end of the pulse. Hence, the magnetron requires a fairly rectangular modulating pulse.

3. DRIVER MODULATOR SYSTEMS

The triode type of r-f generator may be either self-pulsed or externally-pulsed, while the magnetron is always externally-pulsed. The general requirements of the modulating or pulsing system are about the same for both types. When the pulse is formed in low-power circuits and then amplified to produce the actual transmitter pulse, a driver is commonly employed to shape the pulse and a modulator is employed to produce the required amplification and apply it to the r-f generator.

If the shape of the modulating pulse need not be controlled accurately, the trigger pulse from the timer may be amplified in a power amplifier. This is the simplest form of driver modulator. When the pulse shape and duration must be accurately controlled, as in radar sets of short range, more elaborate circuits are used. Such applications generally require a driver in which the pulse is formed by an artificial transmission line, and then applied to a modulator. The occurrence of the pulse is controlled by the output of the timer.

Bootstrap Drivers

The bootstrap driver uses the trigger pulse from the timer to start the discharge of an artificial line through a gas tube. The pulse formed is amplified by a bootstrap amplifier from which the driver takes its name, and is applied to a conventional modulator.

A simplified circuit for producing a rectangular pulse by the use of an artificial transmission line is shown in Figure 1-24A. The characteristic impedance of the transmission line is 2,500 ohms. The resistor, R2, across which the output pulse is to be developed is

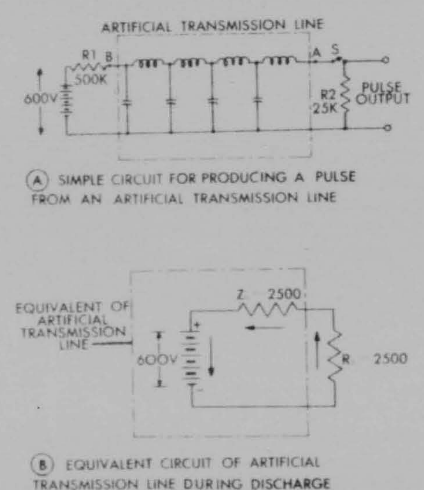

Figure 1—24. Production and Discharge of a Rectangular Pulse.

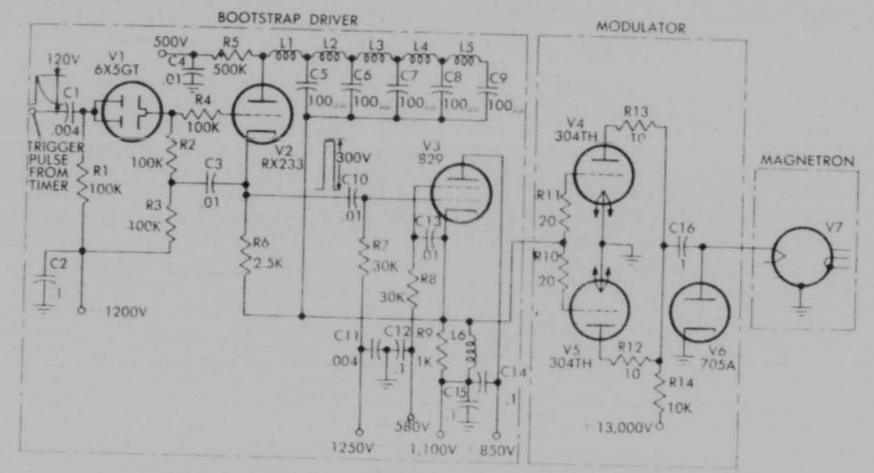

Figure 1—25. Schematic Circuit Diagram of Transmitter with Bootstrap Driver.

equal to this characteristic impedance. Resistor R1, through which the line is charged, is made very much larger than the characteristic impedance so that it is an apparent open circuit during the discharge of the line. The capacitors are all charged to 600 volts if switch S is left open for a sufficient time. If the switch is closed after the line has been charged, a current immediately starts to flow through R2. The line may be considered as a battery with an internal impedance of 2,500 ohms during the discharge time (Figure 1-24B). The voltage across R2 is one-half the voltage to which the line was charged, or 300 volts, since half the available voltage is lost across the 2,500-ohm internal impedance, Z_o. If the network consisted only of capacitors, the discharge would follow an exponential curve, and the voltage across R2 would not be constant. However, the inductance and capacitance of the line are so designated that the discharge rate is practically constant.

The discharge of the artificial line can be explained best as follows: At the instant that the switch 1-24A is closed, the voltage at point A falls to 300 volts. This can be looked upon as a traveling wave of 300 volts applied at point A to reduce the voltage there immediately from 600 to 300 volts. As the wave moves from A to B the voltage across the line is reduced from 600 to 300 volts. On reaching point B, the wave sees an open circuit, since resistor R1 is very large. The wave is reflected without change in sign, and immediately reduces the voltage at point B from 300 volts to zero as the wave travels back to point A, and the remaining 300 volts across the line is canceled out. On reaching point A, the wave has reduced the voltage across all sections to zero, the wave itself disappearing because it is absorbed by a load which matches the characteristic impedance of the line. The pulse formed across R2 by the line discharged lasts for the time required for the traveling wave to move from the switch end of the line to the open end and back.

The complete circuit diagram of the transmitter with a bootstrap driver is shown in Figure 1-25. A thyrator, V2, is used instead of the mechanical switch shown in Figure 1-24A, to discharge the artificial transmission line. The line is connected between the 500-volt and 1,1000-volt taps on the power supply, so that it is charged to a voltage of 600 volts through resistor R5.

A positive-going timing pulse with a steep leading edge is applied to the driver through

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coupling capacitor C1 and isolating diode V1. The positive trigger pulse causes the thyratron V2 to ionize. The current which flows through V2 must come from the discharge of the artificial line because R5 is too large to allow the flow of current sufficient to maintain ionization. The discharge of the artificial line through V2 and R6 produces a —300-volt pulse across R6 during the discharge.

Tube V3 is a double beam-power tube but for convenience it is shown in Figure 1-25 as a single tube. The tube normally is cut off, since its cathode is connected to the —1,100-volt tap and its grid is connected to the —1,250-volt tap on the power supply. The net bias on the tube is therefore —150 volts, which is ample to prevent conduction. When the artificial line discharges, the —300-volt pulse developed across R6 is coupled to the grid of V3 through C10, causing the tube to conduct strongly. The cathode of V3 rises from 1,100 volts below ground to a positive potential with respect to ground because of the voltage drop across R9.

The life of thyraton V2 is shortened by positive ion bombardment of the cathode if the grid is driven sufficiently negative to cause acceleration of the ions toward the cathode. This condition is avoided by using diode V1 and capacitor C3. The trigger pulse is coupled to the grid of V2 through capacitor C1 and diode V1. The positive swing of the pulse causes diode V1 to conduct and produce a signal voltage across R2 and R3. The drop across R2 is applied directly between grid and cathode of V2 and C3. When the pulse is removed capacitor C1 discharges, but, since the diode cannot conduct, the negative voltage resulting does not appear at the grid of V2. The pulse developed in the cathode of V2 is coupled back into the grid through C3, causing the grid to rise with the cathode, and thus prevents a negative voltage on the grid from this source. Resistor R4 is used to limit grid current through V2. Since gain is essential in the operation of this driver, a bootstrap amplifier is used. The bootstrap circuit includes elements which cause the voltage on the grid of the amplifier tube to rise with the cathode voltage, maintaining a constant signal voltage from grid to cathode. These elements include a source of plate voltage for the preceding tube which is not tied directly to ground, and a means of coupling the rise in potential of the cathode to this plate supply.

The artificial line is the source of plate voltage for tube V2 during the pulse, and is isolated from ground by resistor R5. The only other path to ground is through resistor R9 in the cathode of tube V3. Therefore, as the cathode of V3 arises during the pulse, the entire circuit of V2 is raised the same amount above ground. The drop across R6 is maintained by the discharge of the line, and is applied directly between the grid and cathode of V3. This is the bootstrap action, so-called because the amplifier raises its grid-circuit voltage in order to maintain a constant grid signal. When the artificial line is completely discharged, the voltage difference across R6 disappears, and the potential of the grid of V3 at once becomes —150 volts with respect to the cathode, and the tube is made nonconducting. The modulator tubes normally are cut off by the —1,100 volts applied to their grids through R9. The positive pulse produced across R9 drives V4 and V5 into heavy conduction, so that C16 is permitted to discharge through the magnetron to ground and through V4 and V5 in parallel. Since these tubes are in parallel, the resistors R10, R11, R12, and R13 are necessary to prevent parasitic oscillations. The charge that is lost from C16 during the generation of the r-f pulse is restored to the capacitor during the resting time by a charging current which flows from ground through diode V6, capacitor C16, and resistor R14 to the —13,000-volt supply. The diode is used as a one-way resistor which permits current to flow to charge C16, but which prevents loss of energy during the pulse, since none of the discharge current can flow in the diode. The use of the diode permits more efficient use of the energy stored in the capacitor because a resistance used as a charging element may dissipate as much as 20 per cent of the available energy during the discharge.

Line-controlled Blocking-oscillator Driver

A modification of the circuit of the single-swing blocking oscillator may be used to produce a pulse of accurately-controlled duration

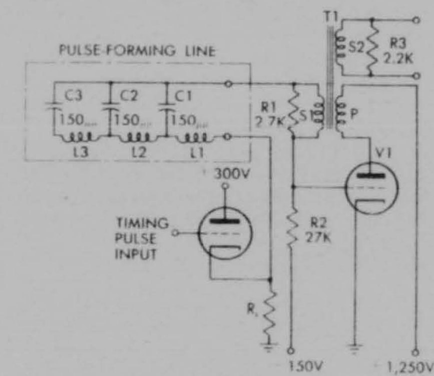

Figure 1—26. Line-Controlled Blocking Oscillator: Schematic Circuit Diagram.

for the operation of a modulator tube (Figure 1-26). An artificial transmission line is used to control the duration of the pulse, since the blocking oscillator itself is unable to produce a square output of controllable duration. One advantage of this type of driver is that it requires only one tube, which makes the driver circuit and the associated power supply simple.

The blocking-oscillator tube V1 is normally cut off because its grid is connected through R2 to the —150-volt bias supply. A positive timing pulse of approximately 110 volts is applied to the circuit through a cathode follower to start the operation. This pulse is coupled across the capacitance of the artificial transmission line and through winding S1 on the pulse transformer to the grid of V1. Although the pulse suffers considerable attenuation in passing through this network, it is of sufficient amplitude at the grid to start conduction in the blocking-oscillator tube.

The plate current of V1 flows through the transformer primary, P, which produces a voltage across this winding. A voltage in secondary S1 is also induced that reinforces the trigger pulse, so that the grid is rapidly driven very positive as soon as conduction is started. If 1,000 volts appears across P, a voltage of 500 volts is induced in S1 because of the 2-to-1 turns ratio of the transformer. Since the voltage induced in S1 is relatively constant during the pulse, it may be represented as a 500-volt battery with polarity as indicated in Figure 1-27.

The artificial transmission line normally is charged to -150 volts through Rk, S1, and R2 from the bias supply for V1. In the equivalent circuit, the line is shown as a resistor in series with a 150-volt battery. Since the two batteries oppose, only 350 volts is available to drive a current through the circuit. The sum of the grid-to-cathode resistance of V1 and the output resistance of the cathode follower is made equal to the characteristic impedance of the artificial transmission line. Therefore, a current i flowing in the circuit produces approximately 175 volts across the line and across the combination or Rk + Rgk with polarity as indicated in Figure 1-27. As long as the current i continues to flow, the voltage developed across Rgk will keep V1 in full conduction.

The additional voltage impressed on the line by the flow of current i in the circuit is of the same polarity as the initial charge. A traveling wave goes down the line, raising the voltage across it to 325 volts. When the wave strikes the open end of the line, it is reflected without change of sign. The wave then comes back toward the source, charging the line to 500 volts as it progresses. At the instant that the reflected wave reaches the input terminals of the line, the current i drops to zero, since the voltage across the transmission line equals the voltage induced in S1, at this instant making the net voltage in the circuit zero. Although the timing-pulse voltage may still

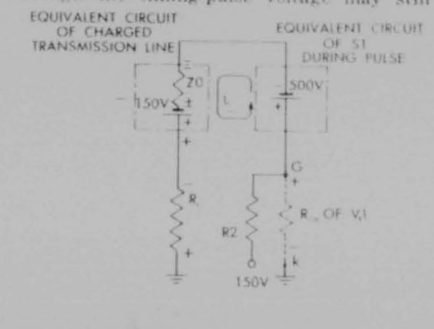

Figure 1—27. Equivalent Circuit of Line-Controlled Blocking Oscillator.

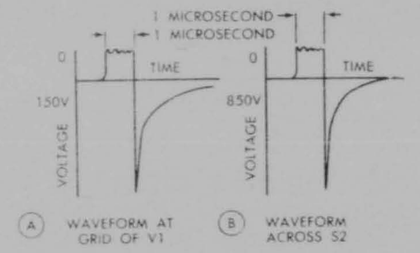

Figure 1—28. Waveforms in Line-Controlled Blocking Oscillator.

exist across Rk, the potential of the grid of V1 drops sharply because of the connection to the −150-volt bias supply, reducing the magnitude of the current flowing in the tube. The duration of conduction in V1, which is equal to the output-pulse length, is controlled by the artificial transmission line. Since the line is designed so that ½ microsecond is required for the wave to travel the length of the line, the output pulse is of 1-microsecond duration.

As the current in the tube starts to fall off, the voltage induced in S1 drops to zero and the artificial line begins to discharge through R2 and Rk. Both of these effects combine to drive the grid very sharply negative, which quickly cuts off the current in V1. The field set up by the primary winding must therefore collapse. In collapsing, a sharp negative surge of voltage is induced in S1 which drives the grid even farther negative. Resistor R1 is used to damp out the oscillations that are excited in the secondary by this negative surge. If no damping were provided, the positive swing of the oscillation might cause false triggering of the circuit.

The waveform of the voltage at the grid of V1 is shown in Figure 1-28A. The slight irregularities in the top of the pulse are due to the fact that the artificial line is only an approximation to a real line. The relatively slow recovery of the grid to its normal bias is caused by the discharge of the capacitors in the artificial line to their normal charge of −150 volts. The flow of current in the primary of T1 also induces a positive pulse in secondary S2. Since the turns ratio between windings P and S2 is 1 to 1, the output developed across this secondary is a pulse of approximately 1,000-volt amplitude (Figure 1-28B).

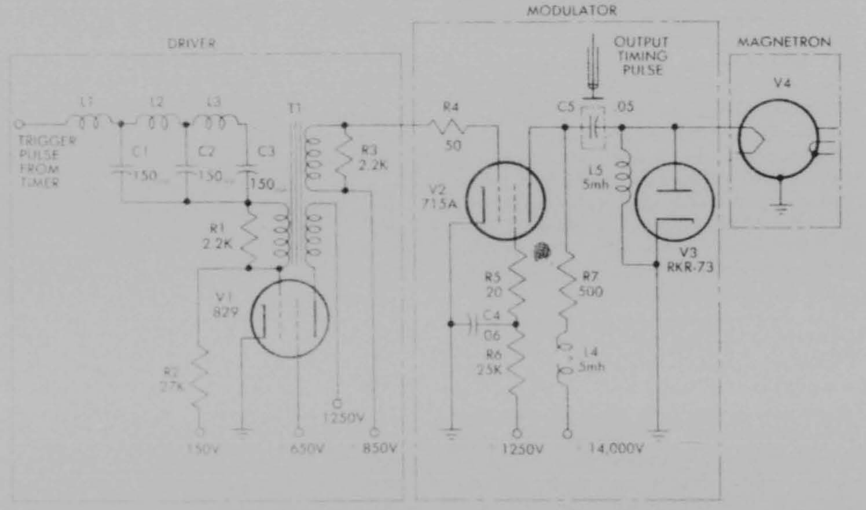

Figure 1—29. Transmitter with Line-Controlled Blocking Oscillator Driver.

The line-controlled blocking-oscillator driver is shown in Figure 1-29 as a component of a complete transmitter circuit. The input to the modulator tube V2 is the 1,000-volt pulse developed across winding S2 of the pulse transformer. V2 is normally nonconducting because of −850-volt bias supplied to its control grid. Capacitor C5 is charged from the 14,000-volt supply through V3, R7, and L4. When the positive pulse is applied to the modulator tube, C5 discharges through the magnetron and V2, generating an r-f pulse.

When the driver-output pulse falls, V2 is sharply cut off. Oscillations are set up in L5 and the distributed capacitance between the magnetron filament and ground by this sudden change. The inductance is put in the circuit purposely to cause oscillations, so that the pulse at the magnetron filament may have a steep trailing edge. For example, Figure 1-30A shows the effect of the distributed capacitance in prolonging the decay of voltage at the magnetron filament. Oscillations set up in the filament circuit by the addition of inductor L5 produce a voltage of the type shown in Figure 1-30B. Since the negative alternations of the oscillation, as at A and B, could cause the magnetron to oscillate, the negative portions must be removed. Damping is usually provided by a diode, so that a waveform of the type shown in Figure 1-30C is produced. The diode acts as a very low resistance across the resonant circuit during the positive alternation, and quickly damps out the oscillations by absorbing the energy in the oscillatory circuit. Therefore, no negative alternations occur to cause the magnetron to operate.

Because there is always a slight delay in starting the pulse in a blocking-oscillator driver, it is not desirable to use the trigger pulse for timing the rest of the radar system where short minimum ranges are important. To avoid the complexity that would be involved in attempting to match this delay by some form of delay circuit, a timing pulse is coupled out of the transmitter from the case of C5. Since the case of C5 is connected to one plate of the capacitor, it changes potential abruptly when the modulator is driven into conduction. Therefore, whenever the magnetron is pulsed, a negative timing pulse is coupled out to the rest of the circuit at exactly the same instant.

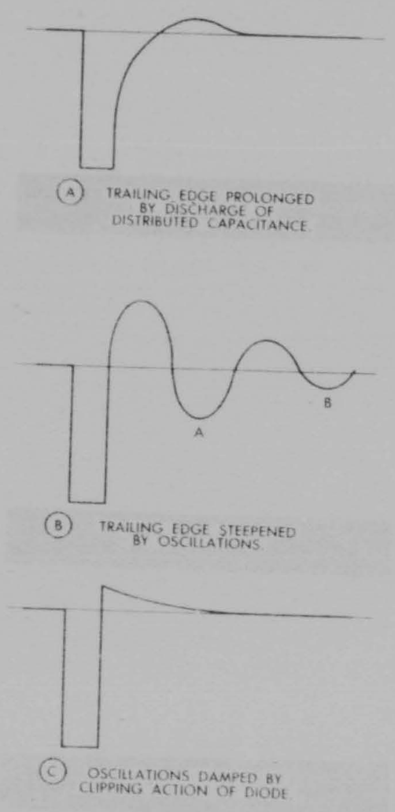

Figure 1—30. Modulation Pulses at Magnetron Filament.

Fixed Spark-gap Modulator

Instead of amplifying a modulating pulse in a series of vacuum tubes, a pulse may be generated at high-power level directly by discharging a pulse-forming line through the r-f generator and a switching device. The switching device in this type of system is usually a spark gap because of the limitations on the power-handling capacity or the break-down voltage of other devices. The obvious advan-

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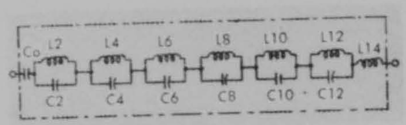

Figure 1–31. Guillemin Line.

tage of this system is that modulator tubes with their heady filament-power drain, are not required. The spark itself dissipates very little energy and the power consumed by the auxiliary controls is small, so that theoretical efficiencies of 80 or 90 per cent are possible.

One disadvantage of the high-level pulse-modulation system is the fact that there is no chance to improve the shape of the pulse after it is generated. In the vacuum-tube pulse modulator the pulse is generated at low voltage and thereafter is amplified in the non-linear amplifiers which saturate at the peak of the pulse. In this case, the artificial transmission line used to form the pulse may be a poor approximation of a real line because irregularities in the flat top of the pulse thus introduced may be clipped in succeeding amplifiers. In the high-level pulse modulator, on the other hand, no such opportunity for shape correction exists. The line employed must be a close approximation to a continuous transmission line.

If an artificial line is to meet this requirement, many sections must be used. Since all of the capacitors must withstand the high voltage, such a line would be very bulky. A means of reducing the physical size of the line is found in the use of the Guillemin line, shown in Figure 1-31. The series capacitor is the only one that need be insulated for high voltage since it is the only one charged. The other capacitors are paralleled by inductances and have voltage across them only during charge and discharge, where they divide the applied voltage.

When the Guillemin line is used in high-level pulse modulation, a very nearly rectangular pulse may be generated with steep rise and fall, and flat-top constant within ±5 per-cent. Modifications of the Guillemin line which use only a few sections have been developed. These networks are usually encased in a metal container filled with insulating compound, and are called "potted lines."

The basic circuit of the fixed spark-gap modulator is shown in Figure 1-32B. The pulse-forming line, which may be either the Guillemin line or the ordinary artificial transmission line, is charged from the power supply through L1 and V1. The inductance of L1 and the capacitance of the line form a resonant circuit so that the voltage across the line tends to oscillate. At the peak of the positive swing the line is charged to a voltage considerably higher than the DC supply. At this instant the trigger pulse is applied to the auxiliary electrode, and the spark gap conducts. The characteristic impedance of the pulse-forming line is made equal to the impedance of the magnetron so that one-half of the voltage on the line is impressed across the magnetron for the duration of the pulse.

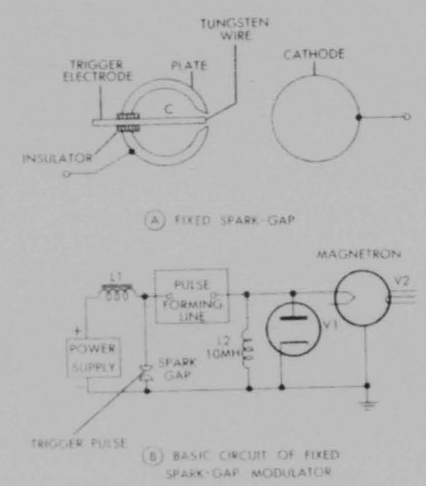

Figure 1–32. Fixed Spark-Gap Modulator.

The spark gap (Figure 1-32A) consists of two spherical electrodes, one of which is hollow. Inserted in the hollow sphere, and insulated from it, is a third electrode. The main gap AB is made large enough so that the voltage between A and B will not break it down.

If the gap between trigger wire C and electrode A is broken down by a trigger pulse, the resulting positive ions will be attracted toward the electrode B and will therefore cause break-down in the space between A and B. The instant of discharge can be controlled accurately in this way. Experience shows that the control of the timing of the discharge is more accurate when the hollow electrode serves as the anode, or plate, for the discharge. The spark stops when the network is almost completely discharged because the voltage across the gap is no longer sufficient to maintain ionization.

A thyratron tube may be used in place of the fixed spark gap in the same circuit. The limitation of the thyratron is that this type of tube cannot withstand a voltage in excess of 27,000 volts, while the spark gap can be used for practically any voltage.

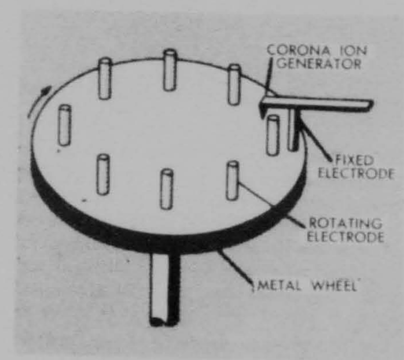

Figure 1–33. Rotary Spark-Gap.

Rotary Spark-gap Modulator

The spark gap is well suited for use in a modulator circuit because it can handle peak currents of 100 amperes or more at very high voltages. However, an arc that takes place in air produces ozone and nitrous oxide which corrode the metallic electrodes rapidly, especially in the presence of water vapor. The life of a fixed spark gap is usually less than 200 hours because of the rapid corrosion of the trigger electrode.

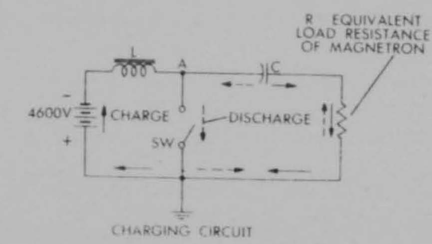

Figure 1–34. Equivalent Circuit of Spark-Gap Modulator.

Another way of breaking down a spark gap is to cause its electrodes to approach each other at the time the gap is to fire. This can be accomplished by rotating one side of the gap on a wheel in such a way that it regularly passes a fixed electrode, as shown in Figure 1-33. On the same bracket with the fixed electrode which serves as one terminal of the main discharge is mounted a small, sharply pointed electrode called a corona ion generator. Near the sharp point of the ion generator the voltage stress is much higher than elsewhere, so that the air is more easily ionized at the point. When the rotating electrode passes between the fixed electrode and the ion generator, the gap between the two main electrodes breaks down quickly because of the initial ionization provided by the ion generator.

Since the spacing of the electrodes which form the gap is not critical, and since the corrosion of the electrodes that takes place is distributed among the several rotating electrodes, the life of the rotary spark gap is much longer than that of the fixed spark gap. If the corrosive gases produced by the spark are removed either by a carbon absorber or blown away by a fan, the life of the rotary gap should be in excess of 1,000 hours.

Because radio-frequency energy is radiated from the spark it is necessary to inclose the mechanism within a metal container to prevent interference with other parts of the radar circuit. In addition, chokes and filters are inserted in all leads to and from the rotary-gap circuit to prevent transmission of r-f energy to other parts of the equipment. The spark gap should be kept at constant pressure to operate consistently. It is especially important that

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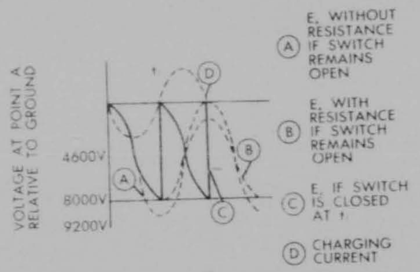

Figure 1–35. Capacitor Charge and Discharge.

the pressure be maintained in aircraft installations, because the breakdown voltage of air is considerably reduced at high altitudes where the air pressure is low.

The pulse-forming network used with a spark-gap modulator may be charged from either an AC or DC source. Since the charge is stored on the capacitors in the network, a capacitive reactance is offered by the network during the charging time. An inductor connected in series with this capacitance produces an oscillatory circuit (Figure 1-34). If switch SW is closed sometime before t_0 (Figure 1-35) the pulse-forming network, which is represented by C, will discharge through R and SW and the potential at A will be zero. If the switch is opened at t_0, a potential of –4,600 volts is suddenly applied to the RLC circuit. This sudden change of voltage sets up a train of damped oscillations. The initial surge of energy oscillates between the magnetic field around the inductor and the charge of the capacitor. If there were no resistance in the circuit, the current would be an undamped sine wave (Figure 1-35D), and the voltage at point A would vary between O and twice the applied voltage, curve (Figure 1-35A). However, with resistance in the circuit, the voltage at point A is a damped sine-wave curve (Figure 1-35B) which will ultimately die out, leaving the capacitor charged to the supply potential of –4,600 volts.

The damping caused by the resistance in the circuit limits the first swing of voltage at point A to about –8,000 volts. The inductance is adjusted to make the frequency of the oscillation equal to one-half the pulse-repetition frequency, so that the voltage at point A will be a maximum at time t_1. If the switch is closed at this instant, the voltage at point A falls to zero (curve Figure 1-35C), and the pulse-forming network discharges through R. Since R is equal to the characteristic impedance of the network, a pulse of 4,000 volt amplitude is produced across it by the discharge.

The exact instant of striking the arc in a rotary-spark gap is not easily controllable and the arc may not strike at exactly t_1 for every pulse. Although the voltage at point A does not change greatly within several micro-

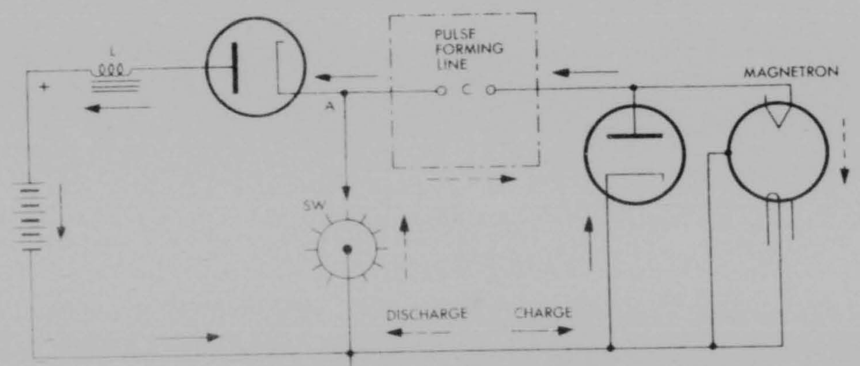

Figure 1–36. Charging Diode in Rotary Spark-Gap Modulator Circuit.

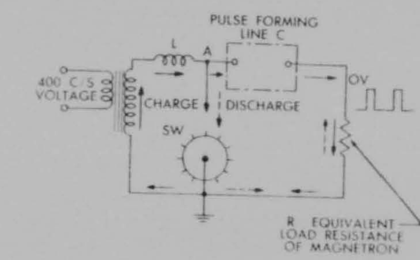

Figure 1–37. AC Charging Through Inductance.

seconds before or after t_1, it is sometimes desirable to connect a diode in the circuit to prevent this voltage from decreasing (Figure 1-36). The diode permits electrons to flow in the direction for charging the network, but at t_1 when the current attempts to reverse direction (Figure 1-35D), the diode becomes nonconducting and prevents any further change of charge on the network. By this means, the network can be charged to nearly twice the applied voltage, and as it will remain at this voltage there is no need of synchronizing the firing of the spark gap with the period of the charging oscillation.

The pulse-forming network may be charged directly from a transformer when connected in a circuit similar to that shown in Figure 1-37. In this case the circuit is not resonant, but the frequency of the applied power corresponds to the DC resonance charging of the type previously discussed. The same variations in the basic circuit can be made.

Improvement in the performance of spark-gap modulators can be had by using transformers which are specially designed to pass a pulse waveform without introducing substantial changes in its shape. Such transformers serve several important purposes in modulator equipment. In the first place they may be used to change the impedance level in pulse circuits, changing from a high-voltage, low-current source to a low-voltage, high-current output, or vice versa. In the second place, the transformer may be used as a polarity-reversing device, as in the blocking oscillator discussed above. In the third place, the transformer may serve to isolate DC sources.

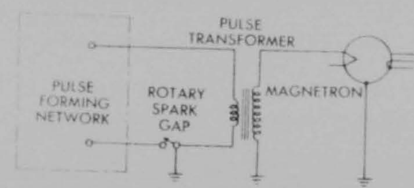

Figure 1–38. Pulse Transformer in Spark-Gap Modulator Circuit.

The most common use of the pulse transformer is illustrated by Figure 1-38. The pulse is formed by a rotary gap discharging an artificial line through the primary of the transformer. The turns ratio is such as to step up the primary voltage to a much higher value to be applied to the magnetron. Since the magnetron impedance as seen by the line is stepped down as well, the pulse-forming network need need not be built to withstand the high voltage of the pulse reaching the magnetron, and can have a lower characteristic impedance. The voltage of the power source for charging the pulse-forming line is correspondingly smaller.

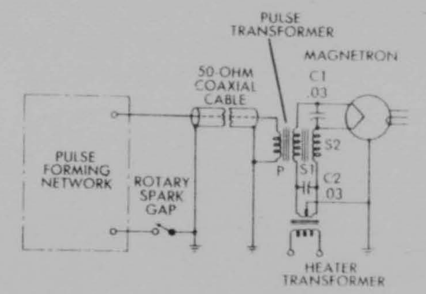

Figure 1–39. Separation of Magnetron and Modulator Circuits.

In many radar installations, particularly those in aircraft, it is desirable to separate the antenna and the bulky power units of the transmitter by a considerable distance. This can be accomplished by running a long coaxial line or waveguide from the magnetron to the antenna. However, long r-f lines tend to make the operation of the magnetron unstable and such long lines should be avoided if possible. An alternative to long r-f lines is to separate

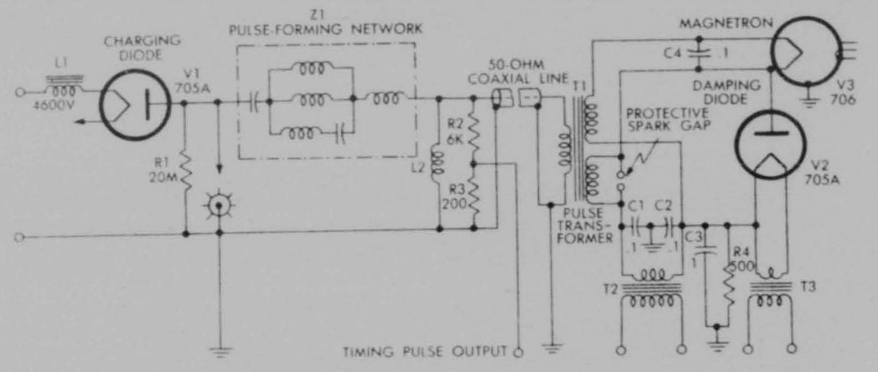

Figure 1—40. Schematic Circuit Diagram of Complete Rotary Spark-Gap Modulator and Transmitter.

the magnetron from the modulator and power supplies, and to connect them by a long cable (Figure 1-39). It is necessary to terminate the pulse cable in its characteristic impedance to prevent reflection of the pulse. Since it is impractical to build a coaxial line of which the characteristic impedance is equal to the static resistance of the magnetron (about 800 ohms), the coaxial line must be terminated in a pulse transformer. The pulse transformer and magnetron are not bulky, thus it is feasible to have them near the antenna.

Two secondary windings are wound on the pulse transformer. When a pulse is applied to the primary, the voltage induced in each winding is negative at the cathode end of the coils. The two secondary windings are effectively connected in parallel for the pulse voltage by capacitors C1 and C2, so that both windings aid in driving current through the magnetron. With two secondary windings connected in this way, the lower ends are nearly at ground potential. Therefore the heater transformer need not be insulated for high voltages. This connection permits the use of conventional heater transformer in this circuit instead of the special transformer, insulated for the full pulse voltage, that was required in the transmitter discussed in Section IV.

In Figure 1-40 is shown the circuit diagram of a complete rotary spark-gap modulator and transmitter. The pulse-forming network is charged to 8,000 volts from a voltage doubler through a resonant-charging circuit consisting of L1, V1, Z1, L2, R2, R3, and the primary winding of T1. Although most of the discharge current flows through the primary of the pulse transformer, some of the current flows through R2 and R3 and through L2. The output of the modulator is a positive-going 4,000-volt pulse. Therefore, a positive pulse of approximately 125-volt amplitude is developed across R3 to be used as the timing pulse for the rest of the system.

The 4,000-volt positive pulse in the primary of the pulse transformer induces a negative 18,000-volt pulse in the secondary windings. Should the load be removed by disconnecting the magnetron, a voltage much larger than 18,000 volts would be developed across the secondaries because of the poor regulation of the transformer. To prevent damage to the transformer from the possible high voltage, a protective spark gap, adjusted to first at 25,000 volts, is connected across one of the secondaries. Should the gap fire, the transformer would be heavily loaded, and the voltage could rise no higher.

The pulse voltage induced in the two secondary windings of the transformer is equalized by bypass capacitors C1, C2, and C4. Since it is desired to keep the lower ends of the two windings nearly at ground potential, capacitors C1 and C2 are connected to ground. The magnetron plate current passes through

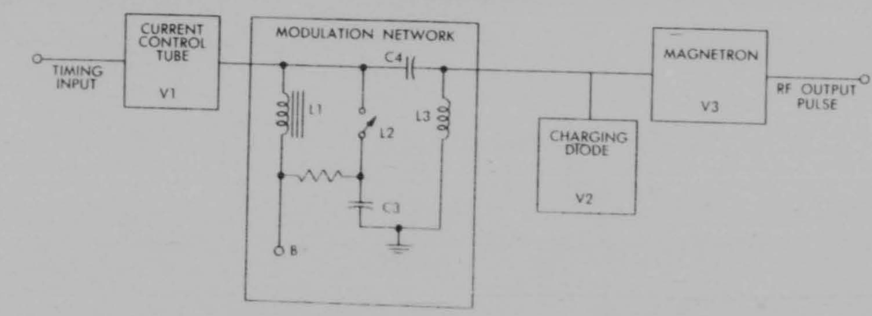

Figure 1—41. Block Diagram of Saturable Inductor Modulator.

the magnetron to ground. The magnetron plate current passes through the magnetron to ground, through R4 and C3 in parallel, and the pulse-transformer secondaries. The voltage developed across R4 is proportional to the average current flowing in the magnetron and the damping diode because C3 filters out the surges. If it is desired to have an approximate indication of the magnetron plate current, a meter may be connected across R4. If no meter is desired, the circuit may be simplified by the elimination of the bypass capacitors, and the center taps of the heater transformers may be grounded to provide a closed circuit for the plate current.

Saturable Inductor Modulator

Instead of producing a low-power pulse and amplifying it, or generating a high-power pulse from an artificial line, a saturable inductor can be used as a switch to control the charge and discharge of a network to produce an approximately square modulating pulse. The block diagram of such a system is shown in Figure 1-41.

The timing input to the current control tube is a square wave. During the positive portion of this square wave, V1 is conducting, and energy is stored in the field around inductor L1. When the tube is cut off, this field collapses, charging capacitor C4 through the charging diode. At the instant that the voltage across the capacitor is a maximum, the saturable inductor switch, L2, is closed and the capacitor voltage is applied across the magnetron through C3.

A saturable inductor can be used as a switch since it can be either a very high impedance or a very low impedance, depending the conditions under which it operates. This wide change of impedance is possible because the core of the saturable inductor, or nonlinear coil as it is sometimes called, is saturated by a relatively low current in the coil. A graph, called a **magnetization curve**, in which the flux density in the core is plotted against the current in the coil, is shown in Figure 1-42. The horizontal portions of the curve are called the saturated region because a current more positive than A or more negative than B cannot cause an increase in the flux density of the core. In the region between A and B the flux density in the core is directly proportional to the current flowing in the coil. Since the voltage across an inductor is proportional to the rate of change of the magnetic flux that links the coil, no voltage appears across it when the core is saturated, even though the current may be changing. With zero voltage across the inductor, it acts as a short circuit; with a voltage induced in the coil by a changing magnetic field, it acts as an impedance

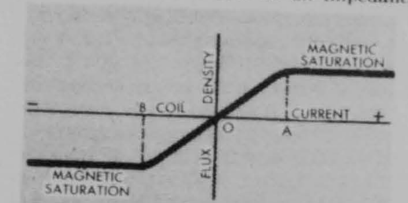

Figure 1—42. Magnetization Curve of Saturable Inductor.

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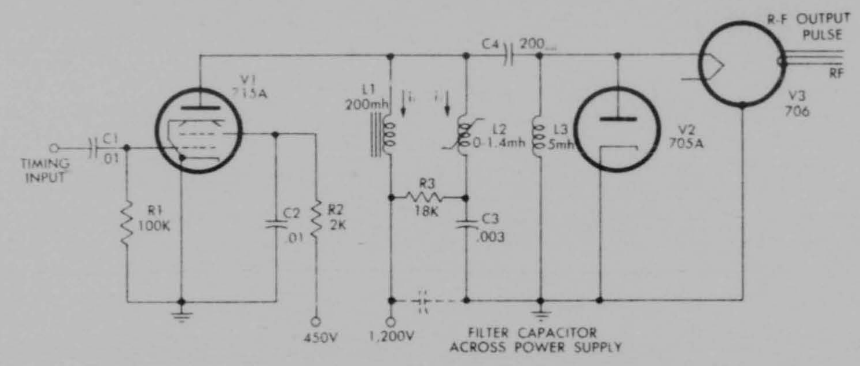

Figure 1—43. Schematic Circuit Diagram of Saturable Inductor Modulator.

which is made high by proper design of the coil. Therefore, when the current through a saturable inductor lies in the region between A and B, it may be considered as an open switch; when the current is beyond either A or B, the inductor is a closed switch.

A schematic circuit diagram of a modulator which uses a saturable inductor as a switching device is shown in Figure 1-43. It should be noted that the symbol for the saturable inductor, L2 is similar to the symbol for a conventional inductor with a line through it to represent its magnetization curve.

The current control tube V1 is normally cut off by grid-leak bias developed by C1 and R1. When the timing square wave swings the grid of V1 positive, current i_1 and i_2 begin to flow in plate-load inductors L1 and L2. Current i_2 quickly builds up to a value in excess of saturation value, so that L2 becomes a low impedance.

At this time, C3 quickly discharges through L2 to the voltage at the plate of V1. Although L2 offers very little impedance to a further change of current in this branch of the circuit the magnitude of i_2 is limited by resistor R3. Inductor L1 is shunted by a high impedance, whether L2 is saturated or not, so that most of the plate current of V1 must flow through L1. As the current i_1 continues to increase, energy is stored in the magnetic field around L1.

When the current-control tube is cut off by the negative swing of the timing square wave the field around L1 starts to collapse. A high voltage with polarity as shown on L1 is induced across L1 by the collapsing field. This voltage is momentarily short-circuited by the low impedance of L2, C3, and the filter capacitance across the 1,200-volt power supply, tending to reverse the direction of flow of i_2. When i_2 decreases to saturation value, L2 becomes a high impedance. At this instant, the energy of the collapsing magnetic field begins to be transferred to capacitor C4 in an oscillatory transient. As energy is transferred to C4, the voltage across it builds up along a sine curve. This voltage reaches a maximum of about 15,000 volts, with the polarity in approximately 10 microseconds, which is equal to a quarter of the period of the oscillation of the resonant circuit made up chiefly of L1 and C4. The path through which capacitor C4 is charged from L1 is through diode V2 and the filter capacitance across the 1,200-volt power supply.

While capacitor C4 is being charged, current i_2 in the saturable inductor decreases from saturation value A to zero and builds up toward saturation value B in the other direction. The time required for this reversal to take place is approximately 10 microseconds. When L2 again is saturated, it becomes a low impedance, grounding the positive side

of C4 through capacitor C3. Since the capacitance of C3 is about 15 times greater than that of C4, and since L2 is a low impedance, approximately 14,000 volts appears across the magnetron. The polarity of the voltage on C4 is such that the magnetron cathode is made negative with respect to the anode, causing oscillation.

Initially inductor L3 is a very high impedance to the discharge of capacitor C4, because the current in the inductor cannot change instantly. However, after about 0.3 microsecond, the current through this inductor has built up to an appreciable magnitude, and L3 effectively shunts the magnetron with a constantly-decreasing impedance. Since the impedance of L3 becomes low, the rate of discharge of C4 is increased, causing the magnetron to go out of oscillation quickly. Within the 0.3 microsecond period, oscillations of a single mode are produced by the magnetron in spite of the fact that the plate voltage decreases from 14,000 volts to approximately 8,000 volts during this time. Although it was pointed out that the voltage impressed on a magnetron should be constant to prevent oscillation in undesired modes, it is possible to operate improved magnetrons with the type of voltage provided by the saturable-inductor modulator without harmful loss of power.

SECTION V—ANTENNA SYSTEMS

1. INTRODUCTION

General

Previous sections of this manual have indicated that the electrical characteristics and physical appearance of radar antenna systems may vary widely. The approximate size of the antenna is determined by the selection of the carrier frequency and the type of installation. The actual design for a given equipment is based on several considerations which control the over-all efficiency and the angular accuracy of the data to be obtained.

Efficiency Considerations

Maximum efficiency of the antenna system demands that each link in the path from transmitter to antenna, and from antenna to receiver, waste as little of the r-f energy as possible. The transmission line used should, therefore, have the smallest possible losses, consistent with the physical types, which can be used for a reasonable size of unit.

In addition to protecting the receiver circuits from burnout and blocking, the T-R switch increases the energy transfer by guiding the signals to their proper destination. During the transmitted pulse the receiver path is closed, and during the resting time the transmitter path is closed. Thus, in each case, the energy is used to produce the desired result, without wasting power in inactive circuits.

Finally, the over-all efficiency can be raised if the particular application for which the system is to be used will permit concentration of the energy into a narrow beam.

Angular Accuracy

The ability of a radar unit to locate targets in azimuth or elevation depends on how well the antenna can select the direction of the return signal. It has been shown in section I that a narrow beam is better able to find the maximum return-signal direction than a wide one. Double-lobe systems still further increase the accuracy of angular measurement.

Back radiation and side lobes tend to confuse the operator, and therefore, decrease his ability to locate targets. Antenna construction which will reduce unwanted lobes in antenna patterns is usually employed to aid in this respect.

2. CONICAL SCANNING

General

The principle of lobe switching can be extended to give accurate azimuth and elevation

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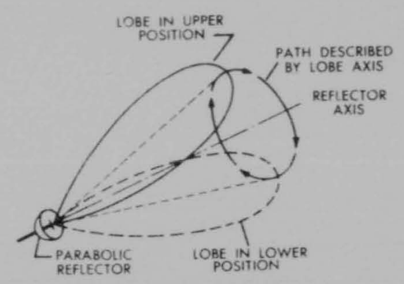

Figure 1—44. Conical Scanning.

simultaneously when applied to antenna systems using parabaloidal reflectors. The name given to this type of operation is **conical scanning** because an off-center lobe is produced which is rotated about the axis of the reflector (Figure 1-4). The lobe axis describes a cone in space around the axis of the reflector.

The echo signal received from a target which lies on the axis of the reflector has the same amplitude for all positions of the lobe. If the target moved away from the reflector axis the signal received varies approximately sinusoidally with the rotation of the lobe. As the axis of the lobe nears the target the signal increases, and as the axis of the lobe moves away the signal decreases. The relative phase of the signal variation therefore indicates the direction of the target from the reflector axis. The magnitude of the signal variation indicates the distance away from the reflector axis to the target.

Conical scanning is applied to micro-wave systems which are used for fire control against aircraft. The circuits which supply the indicator can be used simply to indicate the relative position of the target, or they can be made to track the target automatically as well as indicate its position. The discussion here will be confined to the methods for producing the conical scan.

Off-center Dipole

The simplest method to produce conical scanning is to use a coaxial line terminated in a dipole. The coaxial line is bent sufficiently to displace the electrical center of the dipole slightly away from the focal point of the reflector (Figure 1-45). The coaxial line and dipole are rotated by a scanning motor at a speed of 20 to 60 revolutions per minute.

The apparent source of energy for the parabaloidal reflector is the electrical center of the dipole assembly. Since it is off center with respect to the reflector, the lobe produced will be off center. As the center of the dipole rotates around the axis of the reflector, the lobe is rotated also.

The chief disadvantage of the method illustrated above is that the dipole assembly is not balanced mechanically about the axis of rotation. A second method has been used in which the dipole assembly closely resembles that of the system described previously. The coaxial line is at the center of the reflector, and is perfectly straight and properly balanced. Figure 1-46 shows a dipole; element A is fed in the normal manner by direct connection to the inner conductor. The path for energy flow to element B is made longer by causing the energy to flow from the inside of the outer conductor through hole C and around the outside of the coaxial lines to element B. This manner of feeding, plus the position of the bazooka and the fact that the dipole elements are of different shape, gives an uneven current distribution. The uneven distribution causes the electrical center of the dipole to move from the physical center. Therefore, the energy is reflected from the paraboloid at a slight angle

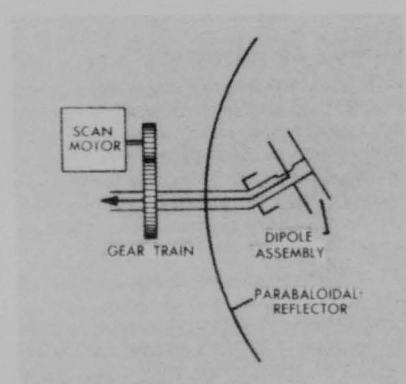

Figure 1—45. Off-Center Dipole.

to the axis. As the dipole is rotated, the point at which the energy is directed describes a circle around the center of the reflector and the reradiated energy describes a cone giving the desired conical scan. The bazooka or quarter-wave balancing section mounted on the outer conductor of the coaxial line also prevents standing waves on the transmission line.

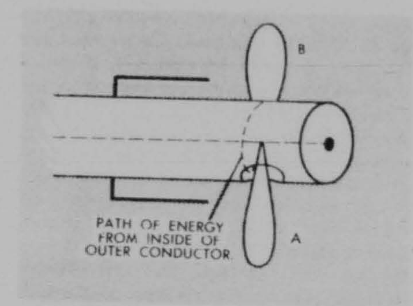

Figure 1—46. Construction of Balanced Conical-Span Dipole.

Waveguide Conical Scan

It is possible to produce a relatively simple system of conical scanning with a round waveguide which may easily be balanced mechanically. Figure 1-47 shows one type which is used. The r-f energy is supplied to a fixed round waveguide through a coaxial line. The inner conductor extends into the guide to act as the coupling probe, and a plunger in the end of the guide is used to adjust the degree

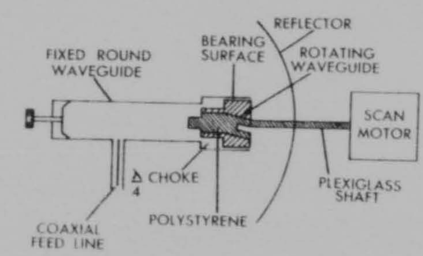

Figure 1—47. Conical Scanning with Waveguide.

of the coupling. A polystyrene-filled round waveguide is fitted in the other end of the waveguide.

The inner end of the polystyrene is of the proper size to match the impedance of the fixed waveguide to that of the rotating waveguide. The rotating waveguide is bent off the center line of the fixed guide in order to produce a beam shift by supplying energy off center to the paraboloidal reflector. The conical scan is produced by driving the offset rotating waveguide through a plexiglass shaft coupled to the scan motor. A small hole in the outer end of the polystyrene filling helps to match the rotating waveguide to the paraboloid and to free space.

The system can be balanced by properly distributing the weight of the metal plug in which the hole is bored to form the rotating waveguide. Radiation through the rotating joint between the fixed waveguide and the metal plug is prevented by a groove a quarter-wavelength deep, which acts as an r-f choke.

SECTION VI—RECEIVERS

1. GENERAL

Introduction

Improved receiver design can increase the usefulness of radar equipment, perhaps more than any other single factor. Only a small part of the energy radiated from the antenna strikes a distant target, in spite of efforts to limit the transmitted energy to a narrow beam. The reflections from the target are scattered in random directions, causing the echo which returns to the set to be extremely small. The receiver must accept signals of perhaps a microvolt or less in amplitude and amplify them to useful magnitudes. The effective range of a radar set is therefore proportional to the ability of its receiver to utilize weak reflected signals. The weaker the signal which the receiver can use, the greater the effective range of the set.

Signal-to-noise Ratio

Theoretically it is possible by using many stages of amplification to build any signal, no matter how weak, to any desired amplitude. However, there are present in all electrical circuits various random disturbances which produce small voltage variations known as noise. In particular, the input stage of the receiver generates such voltages. These are amplified along with the signal voltage in the following stages of the receiver. Noises are generated in the other stages, but these are less important since they are not amplified as much as those which are present in the first stage. If the signal is not at least as large in amplitude as the noise voltage at the input stage, it cannot be recognized at the receiver output and therefore is useless.

A primary consideration in receiver design is to keep the noise lever as low as possible so that, for a given signal, the signal-to-noise ratio is high. If the noise level is low, a weak signal from a distant target may be detected. If the noise level is high, the target has to be much closer before the echo from it is sufficiently strong to override the noise. Thus, the noise generated in the receiver is a factor which affects the useful range of the set. Reducing noise by improved design on a moderately good receiver may extend the range of the set much more effectively than increasing the output power of the transmitter.

The noises which are generated in an amplifier stage include three types. These are thermal agitation, shot effect, and induced noises. All of these include frequency components throughout the entire frequency spectrum, and the amount of noise therefore is affected by the choice of bandwidth for the receiver. In general, a reduction in bandwidth of the receiver reduces the noise voltage, but does so at the expense of pulse shape. The amount of distortion of the pulse shape which can be tolerated is the limiting factor in increasing signal-to-noise ratio by reduction in bandwidth.

Thermal-agitation noises are caused by random motion of free electrons in a conductor. At any instant there are likely to be more electrons moving in one direction than in the other, causing a voltage to develop across the conductor. If the temperature of the conductor rises, the agitation of the electrons increases in both directions so that the instantaneous current is greater. Since the noise voltage generated in a conductor is the IR drop from this current, the amplitude of the noise voltage increases with an increase of either temperature or conductor resistance.

Shot effect is caused by irregular emission from the cathode of a tube. The electron flow in the plate circuit varies slightly in the number of electrons reaching the plate from one instant to another, and in the velocities of the individual electrons. This very small current variation produces a small voltage variation across the load empedance of the tube which is known as noise, since the irregularities are entirely random. When a positive grid is placed in the electron path to divide the electron flow with the plate, the shot effect is magnified because the division of the electrons is also irregular. For this reason, multi-grid tubes are noisier than triodes. Shot effect can be minimized by using a high mutual-conductance tube, since the signal control of the electron stream is greater than in a low mutual-conductance tube for the same relative noise lever. An increase in the space charge by higher filament temperatures is sometimes helpful in smoothing out emission variations.

Stray electrostatic and electromagnetic fields may induce voltages and currents in resistors, leads, and even within the tubes themselves. In addition to the shot effect in the plate circuit, the irregular electron stream causes currents to flow in the grid circuit. The electrons moving past the grid induce charges on it which are dependent on the positions of the electrons. If the flow is constant in velocity and number of electrons, the net result of all electrons will be constant. Actually this is not true, so that a random variation in charge on the grid occurs, with a resulting movement of electrons to and from the grid circuit. This takes place without electrons from the cathode reaching the grid, but by merely passing by. The movement of electrons in the grid circuit produces a noise voltage across the grid circuit which is amplified by the tube. The magnitude of the noise voltage on the grid

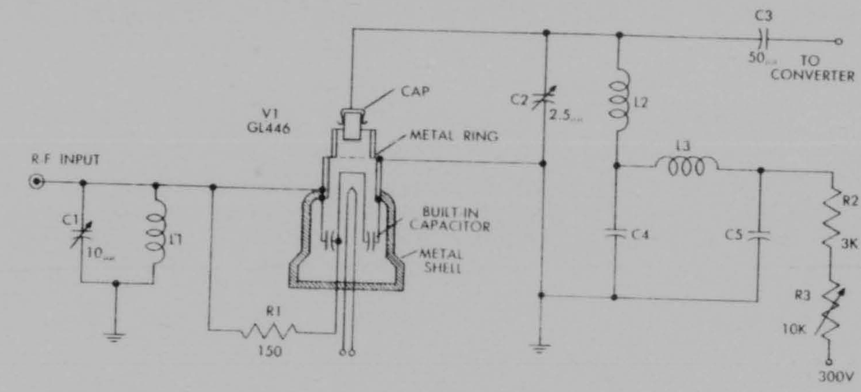

Figure 1—48. Grounded-Grid r-f Amplifier.

resulting from the electron stream increases with frequency, so that noise from this source depends both on bandwidth and the carrier frequency. Any other stray fields external to the tube may produce similar effects, in addition to voltages produced by insufficient filtering of the plate-voltage supply. Long feed lines are particularly susceptible to stray fields. Induced-noise voltages are minimized by low-impedance circuits, shielding, filtering, and short leads.

R-F Amplifiers

The difficulty of obtaining useful amplifications becomes greater as the carrier frequency becomes higher. Because of noise considerations, screen-grid tubes are in common use at the higher radar frequencies. The inductive reactance of the cathode leads at these frequencies causes appreciable degeneration. The signal voltage and part of the noise voltage are affected equally by this degeneration. The noise resulting from random division of current between the plate and screen grid, however, is not affected, because both of the currents flow in the cathode. The result is an over-all reduction of signal-to-noise ratio.

At extremely high frequencies, the capacitive reactance between tube elements becomes important. In triodes, the gridplate capacitance tends to cause instability which may set up oscillations. The grid-to-cathode capacitance tends also to shunt the signal voltage. The result is to limit the possible gain of the tube. The factors affecting the ability to produce amplification have been discussed in section III.

It was pointed out that the irregular emission of the cathode caused an apparent flow of current in the grid circuit without electrons reaching the grid from the cathode. This produces an input resistance to the tube which loads the grid circuit. The higher the carrier frequency, the lower is this input resistance. The electron stream is varied by the applied signal voltage as well, and this lowers the apparent input resistance. Thus the physical grid circuit constructed from inductance and capacitance is paralleled by the apparent input resistance and capacitance of the tube.

For the above reasons, r-f amplifiers have not been used extensively in the microwave region. At the lower radar frequencies, more or less satisfactory gain has been obtained by using tubes of small physical size to reduce interelectrode capacitance and the electron capacitance and the electron transit time. Multiple short leads to the cathode have been used in an attempt to reduce the inductance. A circuit with the grid grounded and the signal applied to the cathode is also useful in extending the high frequency limit of r-f amplifiers since the plate-to-grid capacitance then acts only as a load on the plate circuit,

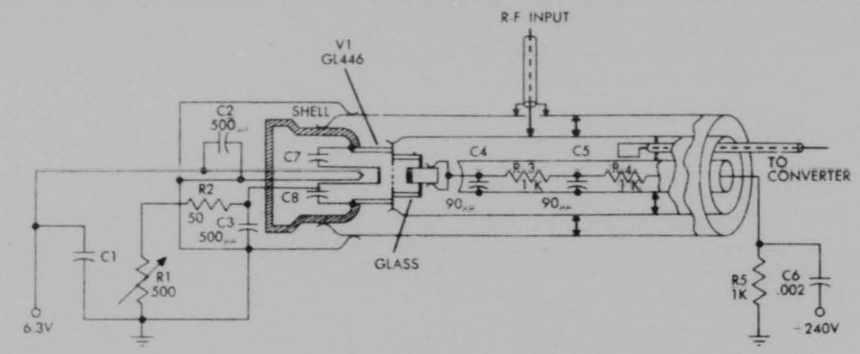

Figure 1—49. R-f Amplifier with Lighthouse Tube.

rather than as a feedback path as in a conventional circuit.

A tube which lends itself well to the grounded-grid type of circuit, or to circuits using tuned concentric lines, is the lighthouse triode. The heater and cathode connections are made to pins in a standard octal tube base. The plate connection is made to the cap, and the grid connection is made to a ring encircling the tube about halfway between the cap and the shell. This construction allows the tube to be made rugged with less interelectrode capacitance for the small spacing than in conventional triodes. A circuit using this tube as an r-f amplifier is shown in Figure 1-48. The coaxial cable carrying the signal is connected directly to the cathode shield. The signal voltage which appears across the tuned cathode circuit C1, L1, is coupled to the cathode by the capacitance between the cathode and a shield. Since the grid is grounded, the application of a signal to the cathode controls the plate current of the tube. Bias is developed across resistor R1. The plate coil L2 is tuned to resonance by capacitor C2. A filter network L3, C4, C5 bypasses to ground any r-f in the plate voltage lead. The resistors R2 and R3 permit the adjustment of the operating voltage to the proper value of from 200 to 250 volts.

Another r-f amplifier using a lighthouse triode and tuned by concentric lines is shown in Figure 1-49. The r-f input is tapped directly on the grid line. The cathode is coupled to the outer conductor of the grid-cathode line by the capacitors C7 and C8 which are built into the tube, and bypass radio frequency from the metal shell that forms the base of the tube to the cathode. Grid bias is furnished by the potentiometer R1 which is set to give the correct plate current. Plate voltage is supplied through the filter made up of C4, C5, and R3 located inside the plate line. Coupling to the next stage is made by means of a pickup coil positioned between the grid and plate lines. Because of the grid-plate line, some regenerative amplification may be realized. Oscillation is prevented by proper loading and location of the grid input tap.

Blocking and Recovery Time

The receiver, though partially protected by a T-R device, receives a strong signal directly from the transmitter. This signal may overdrive and block the receiver and render it insensitive to signals which follow shortly afterward. Thus, the minimum range may be seriously impaired by the receiver's inability to detect signals from nearby targets. The blocking results from excessive bias developed on one of the tubes by the signal, usually in a video stage which is resistance coupled. The blocking bias may be developed by grid current, or by excessive current through a cathode biasing resistor if it is bypassed by a capacitor. The stages preceding the second detector are not usually subject to blocking because the signal has not been amplified sufficiently to overdrive the tubes, since inductors rather than resistors are used in the grid leads, and because any cathode biasing resistors are unbypassed.

Blocking in the video stages can be prevented, or its effect minimized, in several ways. A gate pulse applied to one or more of the i-f stages may either bias the tubes to cut-off or remove the supply voltage for the duration of the transmitted pulse. When it is necessary to receive weak signals at the earliest possible moment after the transmitted pulse, as in AI equipment, gating is used. If the second detector produces negative pulses, the first video stage may be used as a limiter. Any signal of too great amplitude merely drives this tube to cut-off and its output is limited to a predetermined maximum amplitude. If the bias is supplied from the power supply through a voltage divider which draws a large current, any excess conduction by the tube produces only a negligible voltage change in the biasing resistor. When blocking does occur, its duration is determined by the time constants involved. The effect can be made less objectionable by making the time constants, and consequently the recovery time, as short as is practicable. By leaving the cathode resistor unbypassed, its time constant is made practically zero.

SECTION VII—INDICATORS

1. GENERAL

Types of Scan

The basic types of data presentation have been described briefly. The use of one or more types of scan in a radar set is governed by the application to which the set is to be put. As more and more uses are found for radar, the indicators are modified from the simple, basic types of scans to more complex scans which fulfill special needs by presenting all necessary data on one oscilloscope.

In search or early-warning sets it is desirable to view as large an area as possible and to track several targets simultaneously. For this application, the PPI-scan is very useful, and it is frequently supplemented with an A-scan so that the character of the echo may be carefully observed and both ranging and identification may be accomplished easily.

In fire-control or gun-laying sets it is usually desirable to concentrate on only one target, so that some form of gated A-scan or B-scan is often used. Where the target is an aircraft, the indicator must be designed to show the altitude as well as the range and bearing.

A third type of application is the use of radar in aircraft interception. In this case, the radar indicator must provide enough information for one airplane to be pointed at another, so that the type C-scan, or a modification of it, is used in conjunction with a type B-scan.

2. RANGE ESTIMATION

Methods of Estimation

A given range can be represented by the total length of the sweep on a cathode-ray tube screen. If the transmitted pulse occurs at the beginning of the sweep, the range of a target may be estimated by observing the fraction of the sweep length between the transmitted pulse and the echo. Estimations of this kind depend on the judgment of the operator, and are made less accurate by any nonlinearity of the sweep.

If the radar equipment is installed in a permanent location, there may be a number of fixed targets whose ranges are known. Thus, several points on the sweep may be accurately calibrated, and the ranges of other echoes can be estimated with reference to these known points.

Estimation of range is made somewhat more accurate by the use of range markers which divide the trace into equal time intervals. Markers which appear on the sweep it-

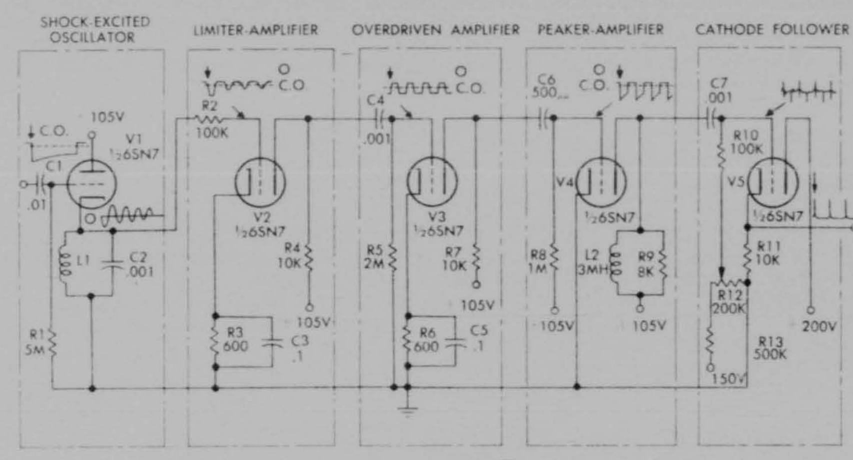

Figure 1—50. Shock-Excited Oscillator Used for Producing Range Markers.

self, rather than as marks on an overlaid scale, are preferable because they compensate for the effects of non-linearity.

Shock-excited Oscillator

A circuit, in which the plate current of a switch tube flows through the inductor of a tank circuit, may be used to produce a damped train of oscillations by cutting off the tube, as explained in section VII, TM 11-466 and Navships 900,016. The frequency stability of this type of oscillation is excellent because the tank circuit is very lightly loaded and the frequency depends in no way on the action of the tube.

One system that is used for generating range markers from the output of a shock-excited oscillator is shown in Figure 1-50. A negative-going square pulse drives the grid of V1 below cut-off at the instant that the sweep starts, thus setting up oscillation in the tank circuit made up of L1 and C2. Sharp, well-defined marker pulses are produced by feeding the output of the tank circuit through the remaining circuits of Figure 1-50. The damped oscillations are limited and amplified by V2 so that the output at the plate is a series of approximate square waves of the same amplitude. Resistor R2 in series with the grid limits the grid current and thus reduces any damping effect on the L-C circuit. The cathode bias developed across R3 and C3 prevents the grid from going extremely positive and thus aids in keeping the grid current low. A low-plate voltage is used to aid in the limiting action. The output of V2 is coupled to the grid of V3 which acts as an overdriven amplifier and produces a good square wave at its plate. The peaker-amplifier tube V4 has as its plate load inductor L2 shunted by resistor R9. The inductor resonates with its distributed capacitance at a frequency of the order of 2 megacycles per second. When the tube is cut off by the negative-going square wave, the coil is shocked into oscillation. The resistance damps the oscillation almost completely before one cycle is completed so that a positive pulse of approximately 0.25-microsecond duration is produced. When the grid swings positive, a negative pulse of smaller amplitude appears at the plate. This has no significance since the following tube is biased below cut-off so that only positive pulses affect its operation. The grid of V4 is returned to a positive potential rather than to ground to insure high conduction in the tube just before the grid swings negative. The large resistor, R8, in the grid circuit limits the grid current to a small value. The output of the pulse generator is fed to a cathode follower which is biased below cut-off. By adjusting this bias so that the positive

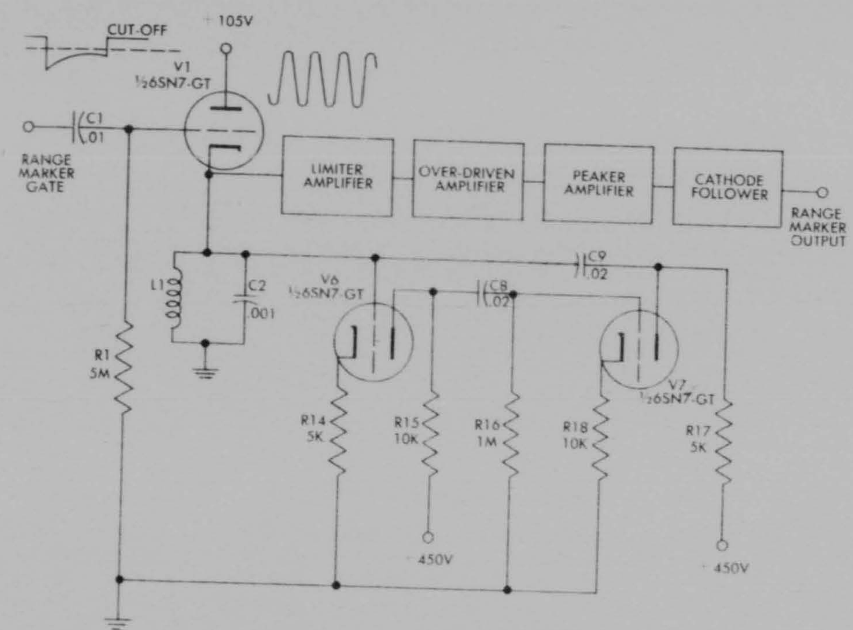

Figure 1—51. Sustaining Multivibrator.

peaks raise the grid above cut-off by the desired amount, the amplitude of the marker pulses can be controlled.

If the oscillations in the cathode circuit of V1 are damped too much to be useful over the entire sweep, a regenerative circuit (Figure 1-51) can be used to sustain their amplitude. The circuits are identical with those of Figure 1-50, with V6 and V7 added. The sustaining circuit is in the form of a multivibrator with a natural frequency of oscillation much lower than that of the input signal. The output of the L-C circuit is coupled directly to the grid of V6, is amplified in V6 and V7, and fed back to the input point in its original phase, having been inverted twice. The degeneration in the two unbypassed cathode resistors prevents excessive gain which would distort the sinusoidal wave generated in the L-C circuit. The frequency of oscillation is the resonant frequency of L1 C2, while the amplitude is held constant by the action of the multivibrator. When current flows in V1, the oscillations are damped out and start again when the current is cut off. The oscillations are used to generate positive marker pulses as discussed in connection with Figure 1-50.

Multivibrator

Range markers may be generated by the type of multivibrator circuit shown in Figure 1-52. The circuit is turned off and on by a signal applied through C1 to the grid of V1. A negative pulse of relatively short duration cuts off V1 and renders the circuit inoperative until the signal goes positive, at which time the sweep also starts. When V1 begins to conduct, its plate voltage drops, and causes the grid of V2 to swing in the negative direction. The current through V2 and consequently the voltage at its cathode decreases. This change, which takes place almost instantaneously, is coupled through C3 to the cathode of V1, driv-

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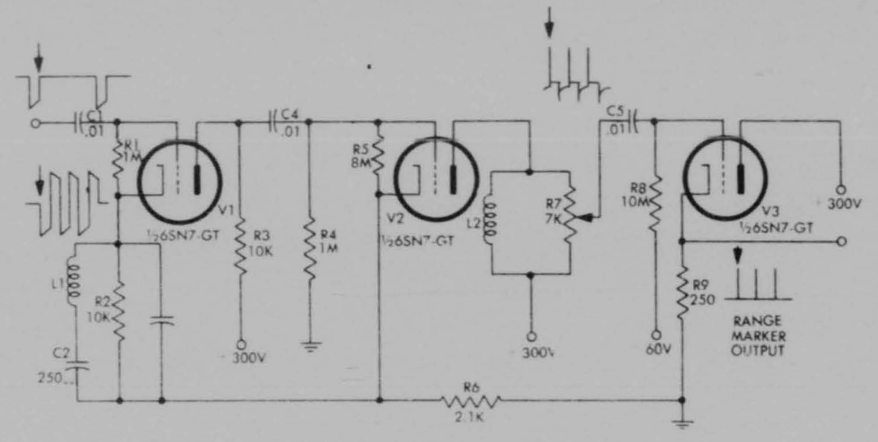

Figure 1—52. Range Marker Multivibrator.

ing it in the negative direction. Since the grid of V1 is held at a relatively constant voltage in respect to ground by the charge on C1, the effect of the voltage coupled through C3 is to increase further the conduction of the tube. This cumulative action cuts off V2 very quickly and drives V1 into saturation.

The plate current of V1 must flow through the three parallel branches in the cathode circuit of the tube. The current that flows in the branches in which there are capacitors causes a change in the charge of the capacitors by withdrawing electrons from one plate of each. This flow of current produces a voltage across the cathode impedance that drives that cathode positive relative to ground. Since the three branches are in parallel, the voltage across each branch must always be the same. The change of voltage that occurs across the branch containing L1 and C2 controls the cathode potential because the rate of change of voltage in this branch is slower than in the others.

As the voltage rises at the cathode of V1, its current becomes less and its plate voltage rises, causing the voltage at the grid of V2 to rise. When the point is reached at which V2 again conducts, a cumulative effect which is the reverse of that previously described, cuts off V1. The tube remains cut off only during the time of one-half oscillation of L1 and C2. At the end of this time, the voltage across the tank circuit has swung to its maximum negative value, causing the start of a second cycle of the circuit action. Thus, V1 and V2 are made conducting alternately at a frequency determined by the value of L1 and C2. Capacitor C3 is used principally as a means of causing the change from conduction to nonconduction to be abrupt. Resistor R2 is used to damp the oscillatory circuit so that the stopping of oscillation may be controlled by the gate voltage applied to the grid of V1.

Since V2 is cut on and off abruptly, sharp market pulses can readily be produced in the plate circuit. The action of the plate load impedance is similar to that described in the peaker-amplifier of Figure 1-50. Resistor R7 is a potentiometer which provides a means of controlling the amplitude of the markers. The cathode follower is biased beyond cut-off so that only positive pulses appear in the output.

3. RANGE MEASUREMENT

General

The difficult problem of firing a gun accurately can be simplified considerably if the exact distance between gun and target can be determined. Radar provides a means of find-

ing this distance by measuring the time required for r-f energy to travel out to a target, be reflected, and to return. Precise measurement of range requires the accurate measurement of extremely short time intervals. These intervals are measured by some means of introducing an accurately-calibrated variable delay between the transmitted pulse and the echo pulses on the indicator screen.

Several methods of producing a variable delay to measure range are in use in existing radar equipment. One commonly used method is to shift the phase of the sine wave, which times the indicator relative to the sine wave, which times the transmitter. The phase shift is used to delay the action of some circuit in the indicator by a measured number of electrical degrees, and therefore to measure the time in terms of the period of one cycle of the sine wave. The phase-shifting device usually is geared to a dial which is calibrated in yards or other suitable units of range.

The range of a target may also be measured by the use of a circuit which measures the magnitude of the sweep voltage at the position at which the echo pulse appears on the sweep. This method depends on the comparison of the sweep voltage with a calibrated variable DC voltage, and it is inherently not as accurate as most phase-shifting methods. However, it does find considerable use in search-radar sets in which it is desired to measure range to a fair degree of precision.

Other methods of measuring range include the use of a delay multivibrator, an acoustic tank employing a fixed and a movable crystal, and calibrated control of the position of the sweep relative to a fixed marker on the face of the indicator.

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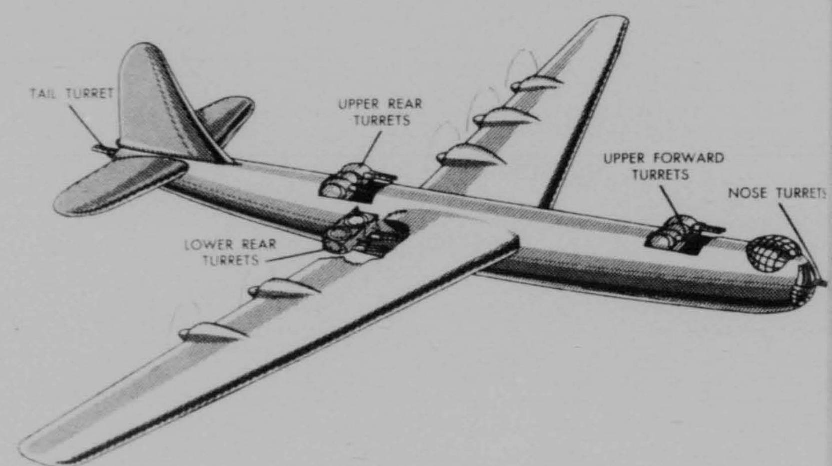
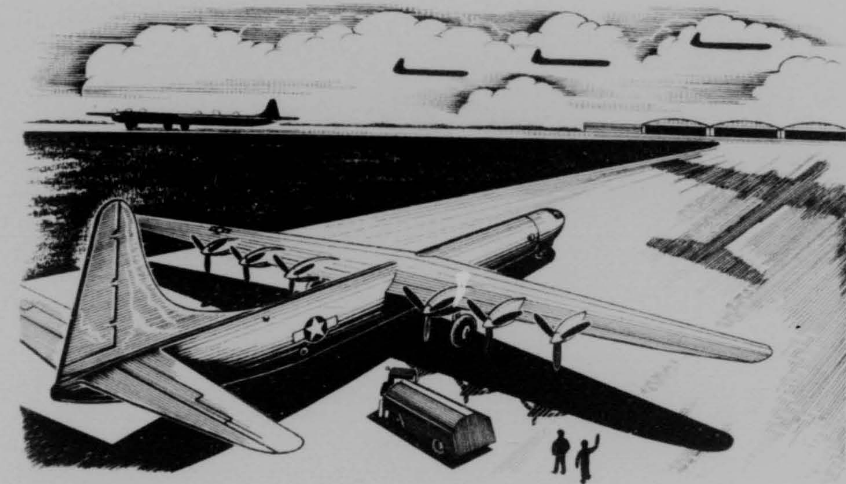


Figure 2—1. Location of Turrets on the B-36.

CHAPTER 2—FIRE CONTROL SYSTEM, THYRATRON



SECTION I—INTRODUCTION

1. GENERAL DESCRIPTION

This chapter contains information on the installation, operation, maintenance, and lubrication of the remote-control turret system used on the B-36 airplane. Information in this chapter pertains to Model 2CFR87 B1, manufactured by the General Electric Company.

The electrically operated remote-control turret system allows the gunners to be located at a distance from the guns which they control. It provides for concentration of heavy-fire power on a target approaching the airplane from any direction. The system is designed for operation between the altitudes of sea level and 40,000 feet above sea level, and within an ambient temperature range of —85° C (—121° F) to +52° C (+125.6° F).

There are eight electrically operated turrets; the upper-left forward turret, the upper-right forward turret, the upper-left aft turret, the upper-right aft turret, the lower-left aft turret, the lower-right aft turret, the nose turret, and the tail turret (See Fig. 2-1).

The turrets are remotely controlled and operated from seven sighting stations and one radar set. The seven sighting stations are the upper-left forward sighting station, the upper-right forward sighting station, the upper-left aft sighting station, the upper-right aft sighting station, the lower-left aft sighting station, the lower-right aft sighting station, and the nose sighting station. The GFE radar set is type AN/APG-3.

The B-36 remote-control turret system has seven gunners and the AN/APG-3 radar operator. Each of the seven gunners operates an optical sighting station which controls one turret. No interchange of control between

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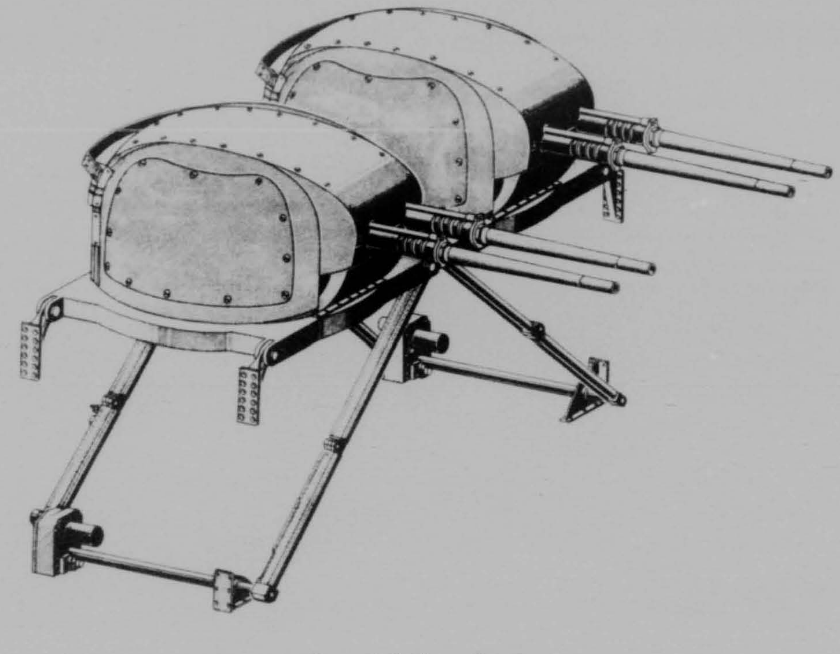

Figure 2—2. Upper Turrets.

gunners is provided. There are four upper-turret gunners, two lower-turret gunners, and a nose-turret gunner. The tail turret is controlled by the AN APG-3 radar operator.

Each turret is armed with two 20-mm guns. The guns move in elevation independently of turret rotation in azimuth. Automatic electric gun chargers and ammunition boosters are common to all eight turrets. The upper and lower turrets are retractable into the fuselage of the airplane. Each gun has a separate ammunition box with a capacity of 650 rounds. The ammunition boxes are furnished by the airplane manufacturer. There is no retraction mechanism, fire interrupter, or contour follower on the nose or tail turrets. All turrets contain Selsyn control transformers which are tandem mounted (Figures 2-2 and 2-3).

Upper Turrets

There are four upper turrets: upper-forward left and right and upper-aft left and right (Figures 2-2 and 2-3). All have approximately 26 degrees downfire and 90 degrees upfire. Rotation in azimuth is limited to 200 degrees, i.e., 100 degrees forward and 100 degrees aft from a position straight out to

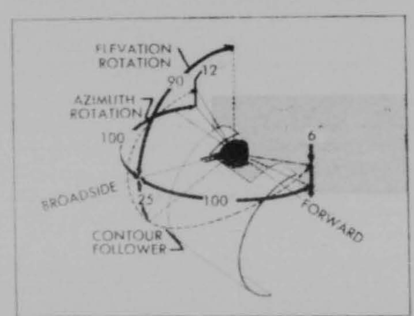

Figure 2—3. Schematic Showing Upper Turret Movement in Azimuth and Elevation.

the side. The contour follower raises the guns in both the forward and aft positions to prevent the guns striking the airplane structure. A fire interrupter prevents self-inflicted damage to the propellers, wing, and tail. The retraction mechanism extends the turret to the firing position and retracts it into the fuselage when desired. Other components of all upper turrets are: gun chargers, DC motors, and AC motors (Figures 2-4 and 2-5).

Lower Turrets

There are two lower turrets, lower-aft left and right (Figures 2-4 and 2-5). They have approximately 26 degrees upfire and 90 degrees downfire. Rotation in azimuth is limited to 200 degrees, i.e., 100 degrees forward and 100 degrees aft from a position straight out to the side. The contour follower lowers the guns in both the forward and aft positions to prevent the guns striking the airplane structure. A fire interrupter prevents self-inflicted

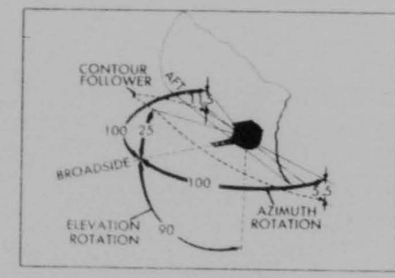

Figure 2—5. Schematic Showing Lower Turret Movement in Azimuth and Elevation.

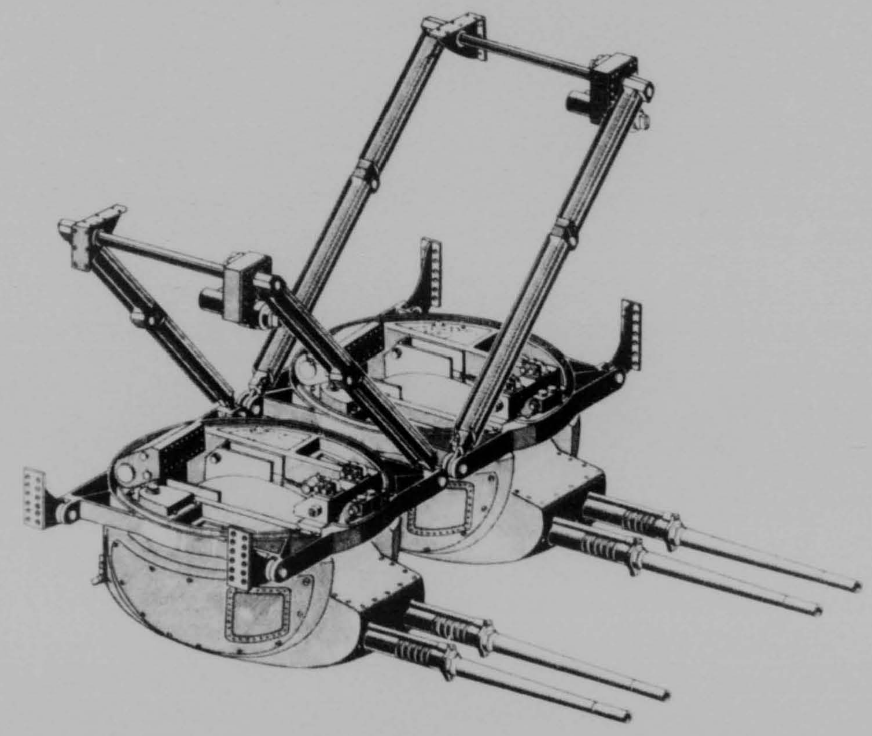

Figure 2—4. Lower Turrets.

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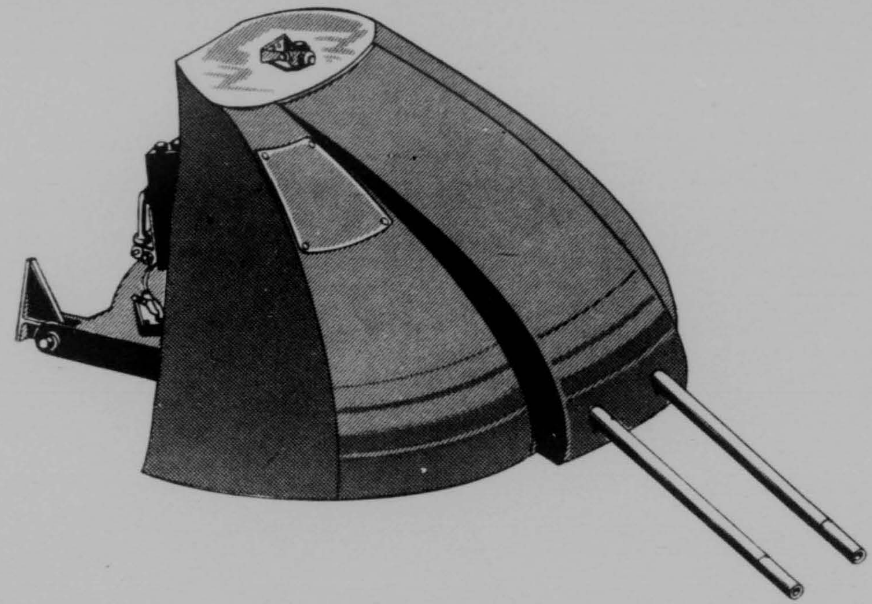

Figure 2—6. Nose Turret.

damage to the propellers, wings, and tail. The retraction mechanism extends the turret to the firing position and retracts it into the fuselage when desired. Lower turrets are essentially the same as upper turrets but, due to their location in the inverted position, minor adaptations are necessary. Used cartridges, for instance, are ejected into space. Other components of lower turrets are: gun chargers, DC motors, and AC motors.

Nose Turret

There is one nose turret (Figures 2-6 and 2-7). It is located in the upper part of the nose, above the gunner and bombardier. It has approximately 28½ degrees downfire and 30 degrees upfire. Azimuth travel is limited to 30 degrees to the left and right of straight forward. There is no contour follower, fire interrupter, or retraction mechanism. Other components are: gun chargers, DC motors and AC motors.

Tail Turret

There is one tail turret (Figures 2-8 and 2-9). It forms the rear end of the fuselage and has 40 degrees upfire and 40 degrees downfire. Azimuth travel is limited to 45 degrees to the right and left of straight aft. There is no contour follower, fire interrupter, or retraction mechanism. Other components are: gun chargers, DC motors, and AC motors.

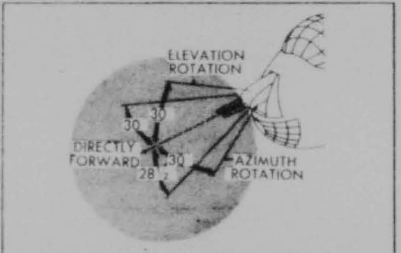

Figure 2—7. Schematic Showing Nose Turret Movement in Azimuth and Elevation.

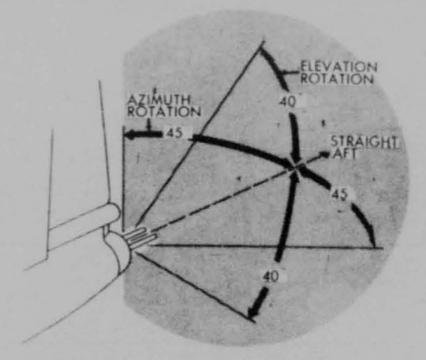

Figure 2—8. Schematic Showing Tail Turret Movement in Azimuth and Elevation.

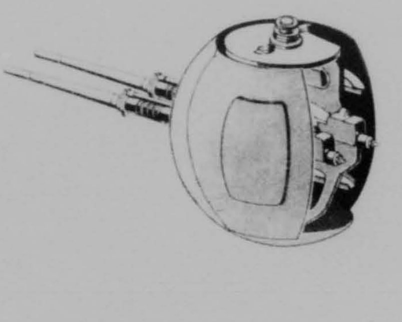

Figure 2—9. Tail Turret.

2. GENERAL DESCRIPTION OF SIGHTING STATIONS

A sighting station, used by a gunner in tracking and in operating a remotely controlled turret, consists of a retiflector sight and a means of indicating to a gun turret the precise direction in which the sight is pointing. The remote-control turret system contains seven sighting stations so designed that the gunners, protected from the slipstream of the airplane by fixed transparent enclosures, can scan the maximum area from their individual stations. There are three basic types of sighting stations: the yoke, pedestal, and the hemisphere. The yoke type is used in

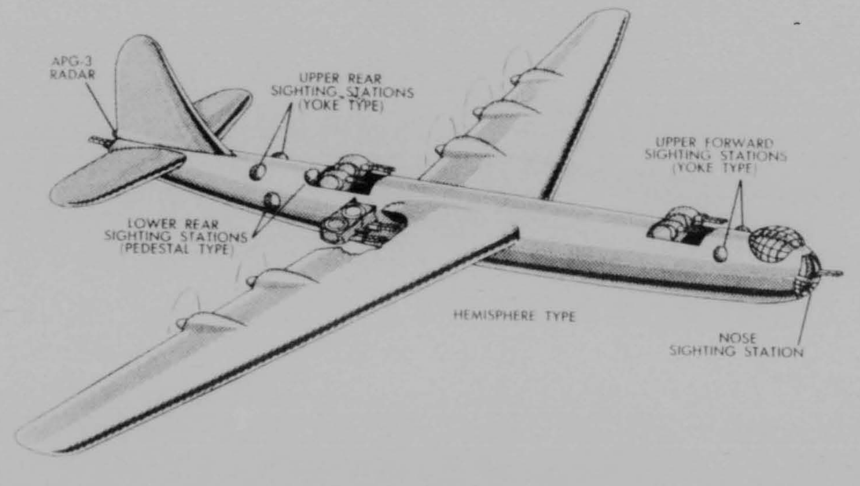

Figure 2—10. Location of Sighting Stations.

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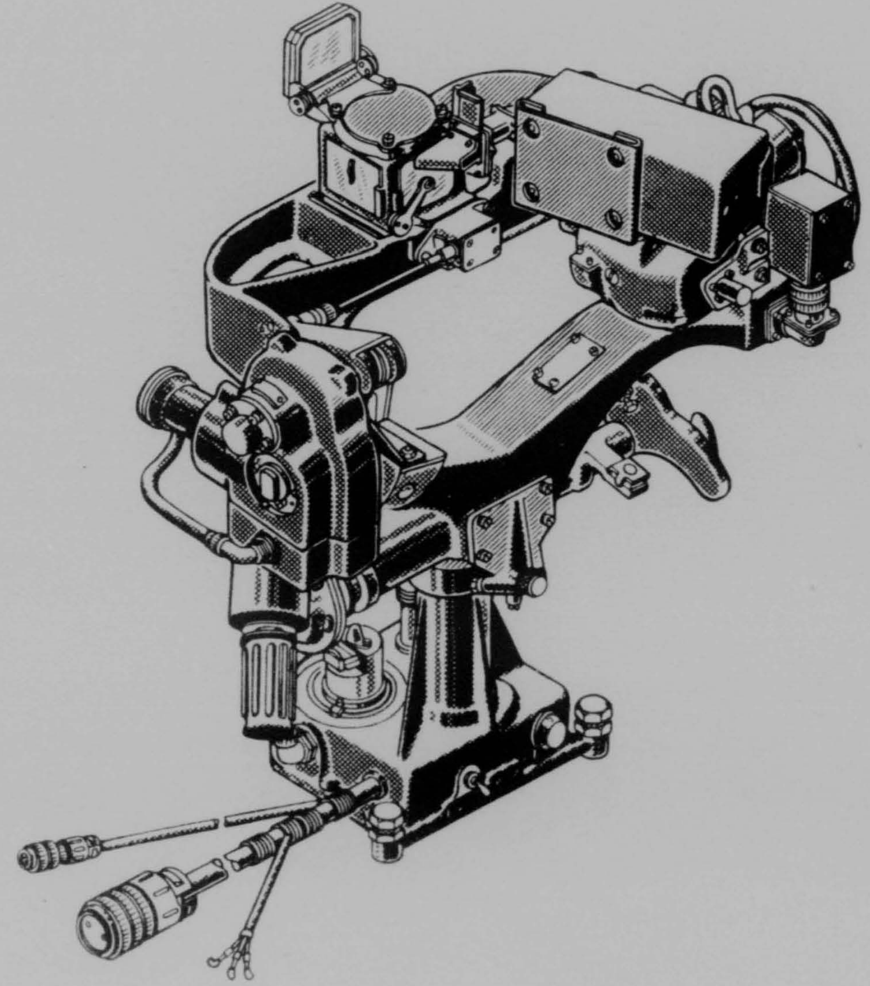

Figure 2—11. Yoke Sighting Station.

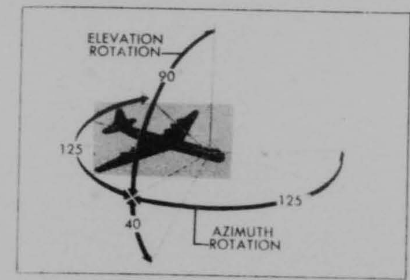

Figure 2—12. Schematic Showing Yoke Sighting Station Movement in Azimuth and Elevation.

the upper sighting stations. The pedestal type is used in the lower sighting stations. The hemisphere type is used in the nose position. Each sighting station contains a gyroscope which transmits lead data to the computer, and a camera which functions when the guns are firing. Selsyn generators are on yoke and pedestal sighting stations (Figure 2-10).

Yoke Sighting Station

The four upper yoke sighting stations are designed to provide the gunner with 90 degrees upfire and 30 degrees downfire, plus additional overtravel. Azimuth travel is 25 degrees greater in each direction than travel. Other components included are: a retiflector sight and a free gyroscope (Figures 2-11 and 2-12).

Pedestal Sighting Station

The two lower pedestal sighting stations can be elevated, depressed, or rotated by the gunner moving the sight handles. Elevation travel is limited to 60 degrees above and 90 degrees below horizontal. Azimuth travel is limited to an arc of 210 degrees. Other components are: a free gyroscope and a retiflector sight (Figures 2-13 and 2-14).

Hemisphere Sighting Station

The hemisphere sighting station, located approximately on the centerline and in the nose pressurized section of the airplane, is a horizontally mounted, double-prism periscopic sight so designed as to give the gunner a complete hemisphere of vision. The apex of this hemisphere is a horizontal line looking dead

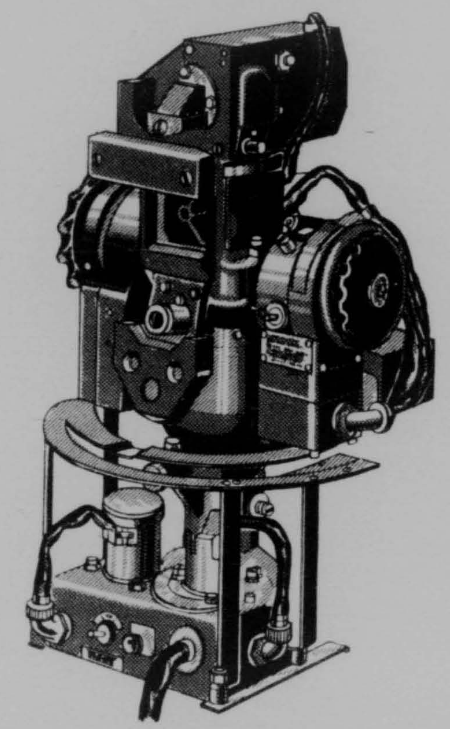

Figure 2—13. Pedestal Sighting Station.

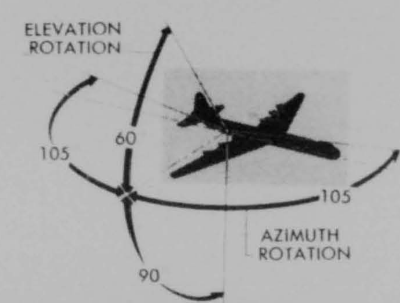

Figure 2—14. Schematic Showing Pedestal Sighting Station Movement in Azimuth and Elevation.

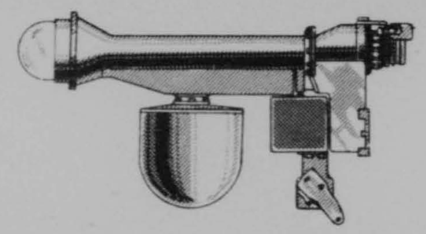

Figure 2—15. Hemisphere Sighting Station.

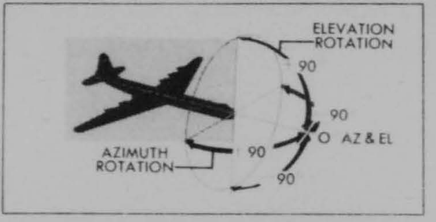

Figure 2—16. Schematic Showing Hemisphere Sighting Station Movement in Azimuth and Elevation.

ahead at zero degrees in azimuth. The gunner, without changing his position, can see 90 degrees to the right and left of zero degrees in azimuth as well as 90 degrees up or down of zero degrees in elevation. For tracking in azimuth, the gunner turns the handle assembly about a vertical axis approximately twelve inches forward of the eyepoint; in elevation, the gunner twists the handles about a horizontal axis which runs through the two handles. The gunner does not rotate his body as the eyepiece is fixed. The main assemblies of the hemisphere sight include the sight head, the main tube, the radarscope optical leg and tube, the rangefinder, and the main housing. The gear drive assembly contains the azimuth and elevation gear trains. This assembly also mounts the handles, interphone, and the action switches. The gyroscope is mounted below the main tube (Figures 2-15 and 2-16).

Computers

There is a remotely located computer for each sighting station. It is designed to allow the gunner to sight directly on a target and causes the gun axes to change from a position parallel to the line of sight to a position which will cause the projectile to hit the target. To accomplish this, each gunner's sighting station automatically supplies his computer with the relative velocity of his target (by means of gyroscopic measurement), and the azimuth and elevation gun position (by means of Selsyn signals). Each gunner introduces into his computer (by means of the handset located in his control panel) information on altitude, the airspeed of his own airplane, and the outside temperature. The computer then allows for windage and gravity (ballistics), the distance between the sighting station and the centerline of the guns (parallax), and the distance the target travels between the time that the projectile leaves the gun and the instant it strikes the target (prediction). Ballistics, parallax, and prediction corrections are computed and appear in the computer output as a single total correction which is then sent to the Selsyn control transformers on the turrets. Components of the computer include DC motors, differential Selsyns, and control-transformer Selsyns (Figure 2-17).

Thyratron Controllers

The thyratron controller is an electronic device which takes small AC error signals from the Selsyn control transformers and converts them to DC power for driving the turret motors. One controller is required for each turret-sight-computer combination (Figure 2-18).

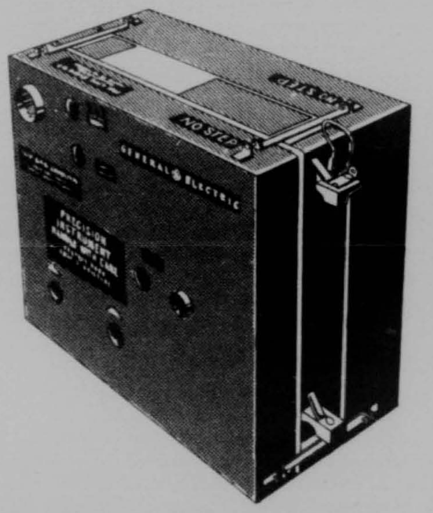

Figure 2—17. Free Gyro Computer.

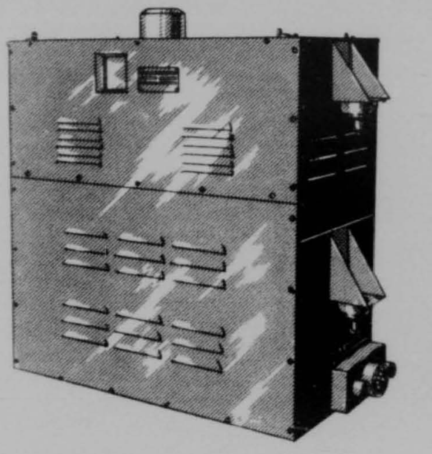

Figure 2—18. Thyratron Controller.

Control Panels

A control panel is provided for each gunner. A uni-switch, ammunition rounds counter, altitude and airspeed handset, circuit breakers, and indicator lights are provided on the control panels for the upper and lower retractable systems. The panels for the nose system and for the tail system omit the indicator lights and some of the uni-switch positions (Figure 2-19).

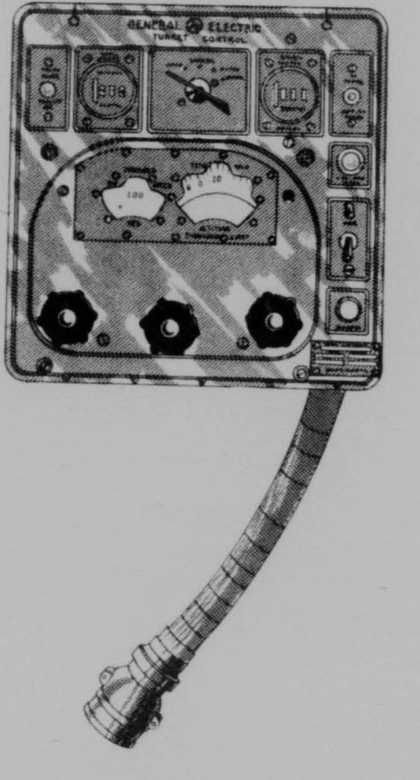

Figure 2—19. Typical Control Panel.

Junction Boxes

A junction box, located near each turret, contains a turret-stowing transformer, charger connectors, firing contactor, retraction-mechanism contractor, and a turret safety switch. In Model 9078151 G-1 junction box, the stowing transformer connections must be changed on a terminal board for each turret location. In model 9167170 G-1 junction box, the junction box is switched to its correct circuit for any particular turret system (Figure 2-20).

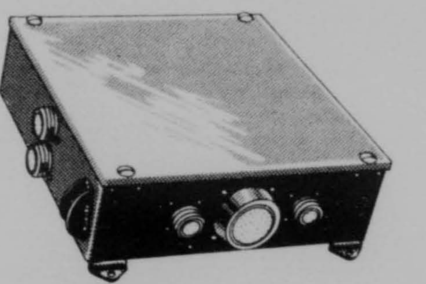

Figure 2—20. Junction Box.

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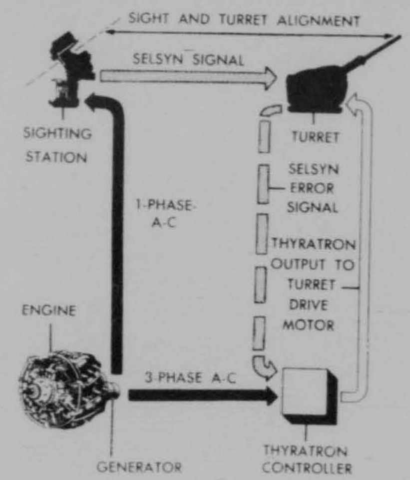

Figure 2—21. Sequence of Power Circulation.

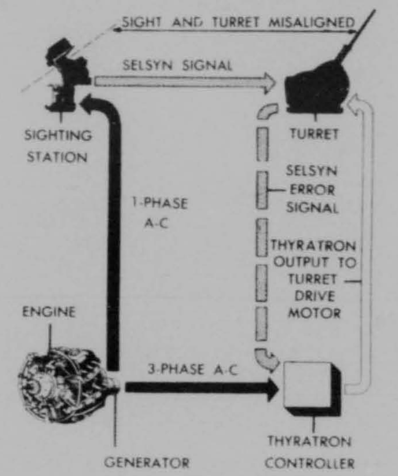

Figure 2—22. Sequence of Operation Steps Caused by Movement of Sighting Station.

Basic Electrical Connections

The electrical circuits for azimuth and elevation turret and gun movement are identical. Therefore, only elevation electrical connections and the elevation operation will be discussed.

Power Circuits. The airplane engine generator furnishes three-phase, AC power to the thyratron controller. Single-phase AC power is supplied to the sighting station. The sighting station is connected electrically to the turret and the turret, in turn, is electrically connected to the thyratron controller. The output of the thyratron controller is connected to the elevation side of the turret (Figures 2-21 and 2-22).

Operation Steps Caused by Movement of Sighting Station. When the gunner moves the sighting station in elevation and causes it to be out of alignment with the turret, the following electrical operations take place:

The sighting station sends an AC signal voltage to the turret, representing the direction of its line of sight.

The turret Selsyn transmits an electrical signal to the thyratron controller representing the difference between the sighting station's line of sight and the turret's line of fire.

The thyratron controller amplifies the error signal voltage and converts it into DC power which is sent to the turret-drive motor to move the turret's line of fire into alignment with the sighting station's line of sight.

When the alignment is complete, the signals from the turret Selsyn to the thyratron controller disappear and the turret is held in its new position.

3. PRINCIPLES OF OPERATION

In the remote-control turret system, the gunner aims the sight at the target and, through a series of electric control and drive units, the guns controlled by the sighting station are made to point at the same target at which the gunner points his sight. Corrections are introduced into the system when the computer operates. There are four basic units in the remote-control turret system: the turret, the sighting station, the thyratron controller, and the computer.

Remote-Control Turret System

Selsyn generators, located on the sighting station, send a signal corresponding to sight

position to the Selsyn control transformers located on the turret. The control transformers have an output voltage (called the "error signal") which is proportional to the difference in the directions in which the sighting station and turret are pointing. When they are pointing in the same direction the error signal is zero volts. The error signal goes to the thyratron controller which furnishes DC voltage to the turret motors proportional to the error signal. The turret motors are then driven in such a direction as to reduce the error signal to zero.

The computer contains Selsyn differential generators which are located electrically between the Selsyn generators and Selsyn control transformers. When no computer connection is necessary, the position signal from the sight is transmitted to the control transformer unchanged. Corrections result in the sight position signal being modified by the addition of the correct correction angles being turned into the differential generator. This new position signal is then sent on to the control transformers. The guns then point in the direction indicated by the sighting station plus or minus the correction angle determined by the computer.

External Power Requirements

The electrical power furnished to the system must meet the following specifications:

208 volts ± 14 volts line to line

120 volts ± 8 volts line to neutral phase, four wire

400 cycles per second ± 14 cycles

Generator must have 15 KW minimum capacity for operating one turret, fast recovery time, and good inherent regulation. Size is determined by peak power requirements.

Note: No DC power is required.

The Selsyn System

A Selsyn is a transformer in which one winding rotates with respect to the other. The voltage developed in the secondary winding is proportional to the cosine of the angle between the two windings.

A Selsyn generator has its primary wound

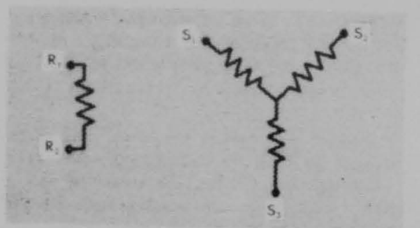

Figure 2—23. Selsyn System Diagram.

on the rotor while the three secondaries, located 120 degrees from each other, are wound on the stator. One end of each of the secondaries is connected together to form a Y-shaped winding (Figure 2-23). The power applied to the primary is 120 volt 400 cycle. When a secondary winding is lined up with the primary winding that secondary has 57.5 volts produced across it. As the rotor is rotated the voltages in the three secondaries vary in magnitude and phase. These voltages are a measure of the position of the Selsyn rotor.

In a Selsyn control-transformer, the three voltages corresponding to the rotor position of the generator are applied to the three winding, located 120 degrees from each other, on the stator. Note that the voltages developed across each of the three stator windings are in phase with each other, while the magnetic fluxes are displaced spatially by 120 degrees. For any combination of the three voltages, there are two positions of the control-transformer rotor which gives zero volts out of the single secondary winding on the rotor. When the rotor is not in the zero position, a voltage is developed which is proportional to the cosine of the angle between its present and zero positions. On one side of the zero position,

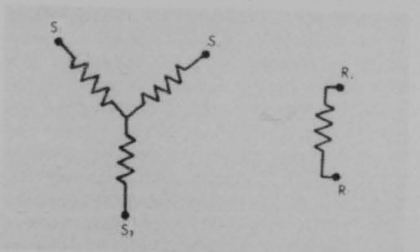

Figure 2—24. Selsyn Voltage Error Signal.

this voltage is in phase with the voltage applied to the rotor of the generator; on the other side, it is 180 degrees out of phase. This voltage is often called the "error signal" (Figure 2-24).

A Selsyn differential generator has three windings on both the stator and rotor, each winding located 120 degrees from the other. When the rotor windings are lined up with the stator windings (Figure 2-25) the three incoming voltages are transformed unchanged to the output side. A rotor rotation of x degrees produces the same change in the output voltages as an additional rotation of x degrees of the rotor of the generator would have caused.

The combination of a 1-speed and 31-speed Selsyn is used in azimuth tracking, and a similar combination is used in elevation tracking. The 1-speed Selsyn makes one revolution for each revolution of the turret, while the 31-speed Selsyn makes 31 revolutions for each revolution of the turret. Therefore, in a 31-speed Selsyn all errors are divided by 31. The turret, however, can line up at 31 different correspondence points; while in a 1-speed Selsyn there is only one correspondence point. Thus, the 1-speed signal insures that the turret follows the sight to within two to three degrees of the correct correspondence point. The 31-speed signal refines the 1-speed signal within these limits, and keeps the turret and the sight accurately aligned.

4. INTRODUCTION TO CIRCUIT DIAGRAMS

For installation and maintenance of the B-36 armament system, any or all of the following types of circuit diagrams can be used. The elementary diagram shows most clearly the electrical relationship between the various circuit components. The schematic diagram shows the approximate location of the devices shown in the elementary diagram and their corresponding interconnections. The wiring diagram shows the physical location of the devices shown in the elementary diagram and their corresponding interconnections. The interconnection or cable diagram shows all the cables running between different units. This diagram includes tables listing the

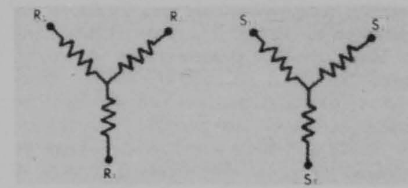

Figure 2—25. Rotor Windings Lined Up with Stator Windings.

wires in each cable and the units to which they are connected.

The Elementary Diagram

(Refer to Table I.) An elementary diagram is used to show in simple form the electrical relationship between components of the circuits in a system. On the elementary diagram different parts of the same device can be shown in different locations, wherever they fit most conveniently into the drawing of the circuit. Combination letter-numeral designations are used to identify the various devices. For example, a relay operating-coil may be designated at K209. Its corresponding contacts wherever they are located, also bear the K209 designation. The prefix "K" indicates that the device is a relay.

The Schematic Diagram

The schematic diagram is made up of the same symbols used in the elementary diagram but it shows the approximate location of the devices by system components.

The Wiring Diagram

The wiring diagram is of value to the maintenance man who may want to observe a voltage across two points on the elementary diagram. Reference to the wiring diagram will show where these actual points are located in the junction boxes and control panels. To aid in identifying circuits, a number system is provided which relates the circuit points on the elementary diagram to the corresponding points on the wiring diagram.

The Interconnection or Cable Diagram

This diagram shows the external connections between the different parts of the sys-

TABLE I

NOMENCLATURE FOR TYPICAL ELEMENTARY DIAGRAMS

	Nomenclature	Location
C1	Gyroscope Filter	Sighting Station
C2	Gyroscope Filter	Sighting Station
CB1	Main Power Breaker, 50A	Thyratron Controller
CB2	Control Power Breaker, 15A	Control Panel
CB3	Firing Control Power Breaker, 35A	Control Panel
CB5	Control Power Breaker, 10A	Control Panel
CR111	Starting Circuit Rectifier	Thyratron Controller
E2	Turret Positioning Terminal Board	System Junction Box
K1	Power Contactor	Thyratron Controller
K2	Power Control Relay	Thyratron Controller
K7	Timer Relay	Computer
K9	Power Interlock Relay	Control Panel
K11	Door Contactor Relay	Door Mechanism
K12	Retract Motor Contactor	Junction Box
K18	Position Out Relay	Junction Box
K20	Charger Relay, Left	Junction Box
K21	Charger Relay, Right	Junction Box
K25	Firing Gontactor	Junction Box
K26	Charger Contactor, Left	Junction Box
K27	Charger Contactor, Right	Junction Box
K99	On Target Interlock Relay	Control Panel
K105	Computer By Pass Relay	Computer
K108(AZ)	Turret Limit Relay, Azimuth	Thyratron Controller
K109(AZ)	Turret Limit Relay, Azimuth	Thyratron Controller
K108(EL)	Contour Relay, Elevation	Thyratron Controller
K109(EL)	Turret Limit Relay, Elevation	Thyratron Controller
K110	Contour Relay, Azimuth	Turret
K113	Backout Relay, Azimuth	Thyratron Controller
K115	Indexing Relay	Junction Box
K116	OOSFI	Thyratron Controller
K205	Computer By Pass Relay	Computer
K213	Backout Relay, Elevation	Thyratron Controller
K215	Indexing Relay, Elevation	Junction Box
K216	OOSFI	Thyratron Controller
K812	Trigger Relay	Computer
R1	Gyroscope Filter	Sighting Station
R2	Gyroscope Filter	Sighting Station
R3	Range Potentiometer	Sighting Station
R4	Range Resistor	Sighting Station
R5	Range Resistor	Sighting Station

	Nomenclature	Location
R6	Reticle Rheostat	Sighting Station
R28	Altitude Potentiometer	Control Panel
R29	Airspeed Potentiometer	Control Panel
S1	Action Switch	Sighting Station
S2	Gun Safety Switch	Control Panel
S3	Turret Safety Switch	System Junction Box
S4	Firing Trigger Switch	Control Panel
S5	Reticle Light Switch	Sighting Station
S6	Camera Switch	Sighting Station
S7	Counter Switch, Left	Turret
S8	Counter Switch, Right	Turret
S9	Charger Switch, Left	Turret
S10	Charger Switch, Right	Turret
S11	Door Limit-open Switch	Door Mechanism
S12	Retraction Limit-extend Switch	Retraction Mechanism
S13	Retraction Limit-retract Switch	Retraction Mechanism
S14	Door Limit-close Switch	Door Mechanism
S15	Fire Interrupter Switch, Left	Turret
S16	Fire Interrupter Switch, Right	Turret
S17	Turret Position Out Switch	Sighting Station
S19	Manual Charger Switch, Left	Turret
S20	Manual Charger Switch, Right	Turret
S21	Computer Out Switch	Sighting Station
S22	Stow Position Switch	Turret
S100	Uniswitch	Control Panel
S101	Uniswitch	Control Panel
S102	Uniswitch	Control Penel
S108	Turret Limit Switch, Azimuth	Turret
S109	Turret Limit Switch, Azimuth	Turret
S110	Contour Position Switch	Turret
S208	Turret Limit Switch, Elevation	Turret
S209	Turret Limit Switch, Elevation	Turret
T1	Filament Transformer	Thyratron Controller
T5	Starting Circuit Transformer	Thyratron Controller
T10	Stowing Transformer	Junction Box

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tem. All internal connections of the units themselves are omitted. The outgoing terminal or circuit numbers are indicated or listed in the tables giving the cable makeup. This type of diagram is very useful for installation and checking purposes.

5. TYPICAL REMOTE-CONTROL TURRET SYSTEM

A group of typical control circuits (representative of any turret system) will be developed in this section, using an upper-forward turret system as an example. A uni-switch controls the operation of these circuits in five steps, from an "off" position to readying the turret for "operation."

Circuits Controlled by Uni-switch

The first position in the uni-switch is the "warm-up" position. This furnishes single-phase AC power to the gun and computer heaters. The "stand-by" position; here AC power is supplied to the time-delay starting circuit of the thyratron controller. "Door open" position; energizes the door motor, opening the turret door. "Operation"; energizes the retraction mechanism motor, and extends the turret into position ready for use (Refer to table II).

First Position—"Off."

Second Position—"Warm-up". When the uni-switch is thrown to the second ("Warm-up") position, a switch is closed and supplies 120-volt, single-phase AC power to the gun and computer heaters.

Third Position—"Stand-by". When the uni-switch is thrown to the third ("Stand-by") position, a switch is closed and supplies 120-volt, single-phase AC power through a transformer to selenium a rectifier. The restifier supplies a DC voltage to contactor coil which closes its normally open contacts, furnishing DC power to the thyratron controller. AC power is also furnished to the Selsyn generators, stowing transformer, gyro, and altitude potentiometer.

Fourth Position—"Door Open". When the uni-switch is thrown to the fourth ("Door Open") position, the normally-open contacts of a switch are closed, sending DC power through a door limit switch to a contactor coil which closes normally open contacts. This furnishes three-phase AC power to the door motor. The door opens until it hits a limit switch, opening the normally closed contacts, de-energizing the contactor coil, and opening the contacts, stopping the door motor.

Fifth Position — "Operation". When the uni-switch is thrown to the fifth ("Operation") position, the normally open contacts of a switch are closed sending DC power through the switches to a contactor coil, closing the normally open contacts supplying three-phase AC power to the retraction motor. The turret extends until it hits a limit switch opening the normally closed contacts, de-energizing the contactor coil, and opening the contacts stopping the retraction mechanism motor. When the limit switch is actuated by the fully extended turret, it also connects DC power to the control power DC bus. The turret cannot operate until this circuit is energized.

Control Power. When the turret is fully extended, the line is energized with a 27-volt DC control power. The line carries the control power to the following components; gun chargers, drive-motor fields and brakes, contour relay, turret limit relays, computer, action switch, reticle light, range resistor, camera motor and heater, and gyroscope motor.

Automatic Stowing. The guns are held in stowed position when the action switch is not depressed. The stowing transformer supplies a fixed signal to the stators of the control transformers through the normally closed stowing relays.

Non-computing Operation. When the action switch is closed, the stowing relays are energized. This replaces the stowing transformer connections to the Selsyn control transformers with connections direct to the corresponding Selsyn generator stators through the normally closed computer by-pass relays. The system is now ready to operate with the computer cut out. The Selsyn control transformers are ready to transmit the intelligence they receive to the thyratron controller.

Computer In-out Switch. When the switch

is closed, the computer by-pass relays are energized. This action inserts the computer into the Selsyn system between the Selsyn generators and Selsyn transformers, allowing the computer to make all needed corrections to the Selsyn signal.

Turret Safety Switch. The manually operated turret safety switch is located on the system junction box. When this switch is open, no DC power is supplied to the system, thus preventing its operation. This is to protect anyone working on the turret.

Firing Circuits—Gun Safety Switch. When the gun safety switch is closed, 27 volts DC power will flow to the contacts of the firing contactor, provided the firing trigger is closed. When this safety switch is open, the firing circuits can not be energized.

Camera Circuit. The camera will operate whenever the firing trigger, the gun safety switch, and the camera switch are closed. Current flows from the DC control power line through the firing switch, to the camera, energizing a relay in the camera, and to ground through the camera switch. Twenty-seven volt DC power is furnished to the camera heater and camera motor from the DC control power line through a relay internal to the camera. The adjustable overrun control causes the camera to operate for a short time (zero to three seconds) after the trigger is released.

Guns Start Firing. If the normally open contacts of the turret limit relays are closed, 27-volt DC power will energize the firing relay coil. This closes the normally open contact and current flows through the gun safety switch, through the firing power circuit breaker, through the fire-interrupters, to the left- and right-hand firing solenoids and to the left- and right-hand charger relay coils. The normally open charger relay contacts close, sending three-phase, AC power to the left- and right-hand chargers. The booster motors are connected in parallel with the gun chargers and operate whenever the firing solenoid is energized. The fire-interrupter switches are located on the switch carriage of the fire-interrupter unit on the turret. If one or both of the fire-interrupter switches are open, the fire of one or both of the guns will be interrupted. The fire-interrupter automatically interrupts the fire of the guns whenever they are trained at some portion of the airplane structure.

Circuits Energized. With the uni-switch in the fifth position, all circuits previously energized in the second, third, and fourth positions are still energized.

Other Circuits Within the System. Out-of-Synchronism Fire Interruption. Whenever the turret is out of synchronism with the sight far enough to transfer from the 31-speed to the 1-speed Selsyn circuits, the firing circuits are interrupted. This prevents the guns from firing while they are slewing into alignment with the sight from an area over 3 degrees away from the line of sight.

Backout Circuit. Whenever the gunner tracks a target beyond the azimuth or elevation limits of the guns, the turret limit switches are actuated, de-energizing the limit relays in the thyratron controller and disconnecting plate voltage from the pulse thyratron in the channel that powered the turret in the direction in which it was moving, and opening the firing circuit. When the sight is moved back into the range of travel of the guns, the channel for the opposite direction supplies power to the turret motor.

Contour Follower Circuit. The downward travel of the upper turrets and the upward travel of the lower turrets is limited by the contour follower by an amount depending on the azimuth position of the guns. This action is necessary to prevent the guns from striking the airplane fuselage and to prevent the line of fire from pointing at gunners' sighting blisters. When the gunner tracks a target beyond the elevation travel of the guns toward the fuselage, a contour limit switch is actuated. This cuts off the power to the azimuth and elevation drive motors, the brakes are applied in both azimuth and elevation motors, and the firing circuit is interrupted. When the contour limit switch cuts off all these circuits, the limit switch cannot close until the turret is moved back off the contour. However, there is a backout circuit for both azimuth and elevation functions which pulls the guns back off the contour as soon as the sight returns to the area of fire. When the sight is moved from the point at which it left the guns on the contour, the guns will step-follow the contour;

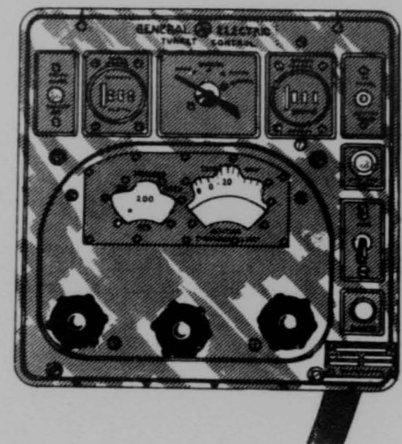


Figure 2–26. Typical Control Panel.

that is, they follow the contour in small increments, or steps, when going either up or down the contour.

Operation of the Contour Follow Circuits. The contour switch is actuated when the guns hit the contour. When normally closed the switch opens, it de-energizes the coils. This de-energizes the elevation and azimuth channels which powered the turret in the direction of travel of the guns. The elevation channel is cut off when the coil is de-energized. The azimuth channel to be cut off is determined by the position of the contour position switch, actuated by the passage of the turret into either the quadrant forward or aft of broadside. It permits the proper channel to be cut off, and maintains a closed limit circuit for the azimuth channel required for power to back the guns off the contour. The turret can then continue to follow the sight in normal operation.

DC Power Supply. A DC supply in the thyratron controller furnishes 27-volt DC control power to the turret system.

Operation Instructions

Starting the System (Figure 2-19). The remote-control turret system is turned on by turning a single uni-switch on the control panel adjacent to the sighting station which is to be operated. The sequence of the switch positions is as follows:

"Off." This is the first position of the uni-switch.

"Warm-up." This is the second position of the uni-switch. It energizes the gun and computer heaters.

"Stand-by." This is the third position of the uni-switch. It energizes the thyratron controller, Selsyn generators, stowing transformer, gyroscope, and altitude potentiometer.

"Door Open." This is the fourth position of the uni-switch. It energizes the door motor opening the turret door.

"Operation." This is the fifth and last position of the uni-switch. It energizes the retraction mechanism and extends the turret into position ready for use.

Warning: When the uni-switch is in the "operation" position the guns will fire, if loaded, when the action switch, gun safety switch, and firing trigger are closed.

Operating the Sighting Station (Figures 2-27 and 2-28). The rheostat (4) on the sighting station is turned on to adjust the reticle to proper brightness. The filament switch (3) on the reticle sight is flipped to make sure that both filaments of the reticle bulb work.

The "computer stand-by" switch (5) on the sighting station is turned to the "in" position. This connects the computer to your sight.

The warning light, which lights when the computer is at "stand-by," must be off.

The azimuth stow-pin (7) is released to permit azimuth movement of the sighting station. If the sighting station moves too easily or too hard, the azimuth friction adjustment (6) is used. The lock nut is loosened with a wrench and the screw turned with a screw driver. Turning the screw clockwise tightens the adjustment while counterclockwise loosens it.

The elevation stow-pin (9) is released to permit up-and-down movement of the sighting station. If necessary, the elevation friction adjustment (11) may be used.

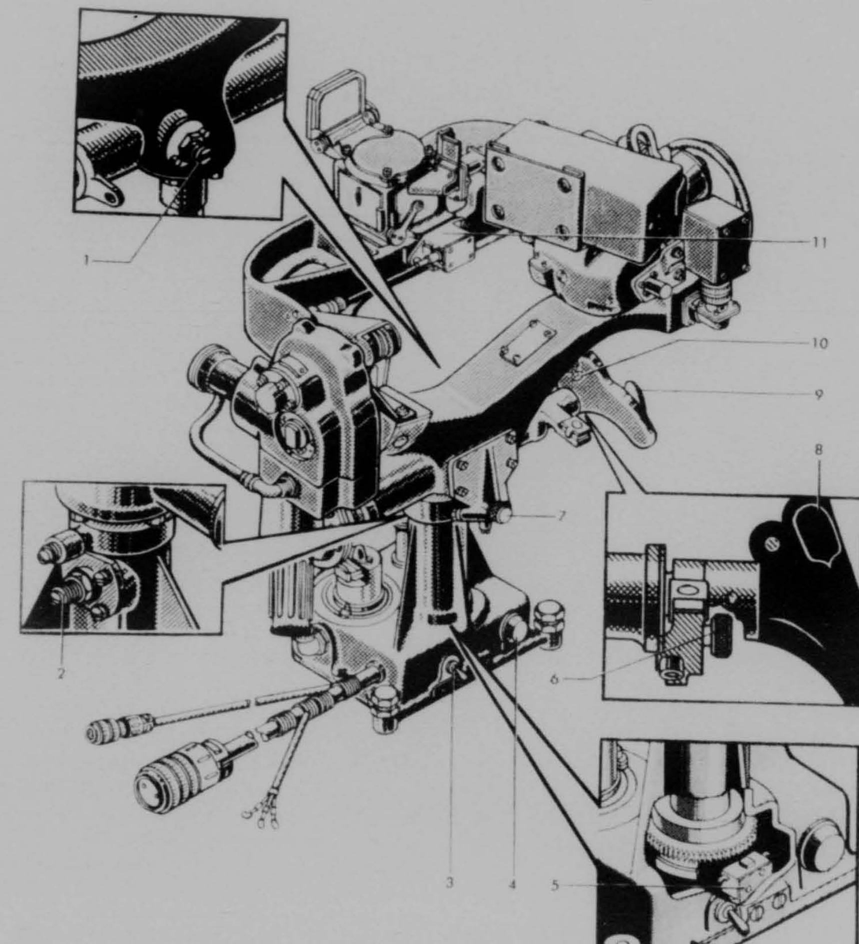
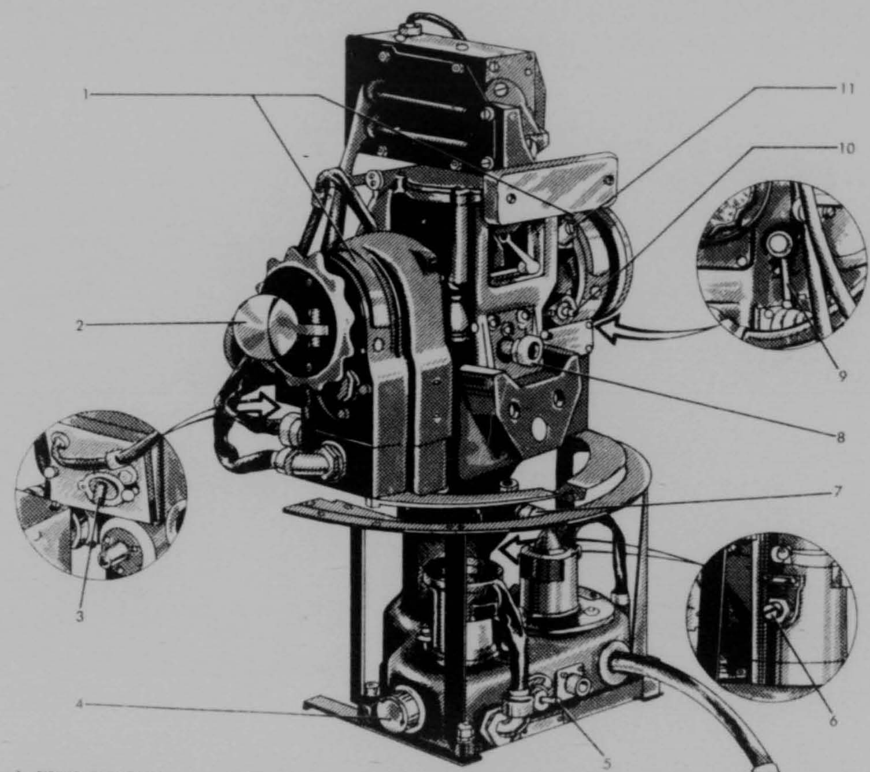


Figure 2–27. Location of Switches and Adjustments on Yoke Sighting Station.



1. FIRING TRIGGERS
2. ACTION SWITCH
3. RETICLE LAMP SWITCH
4. RETICLE LAMP RHEOSTAT KNOB
5. COMPUTER "STAND BY" SWITCH
6. AZIMUTH FRICTION SCREW
7. AZIMUTH STOW PIN
8. TARGET INPUT KNOB
9. ELEVATION STOW PIN
10. INTERPHONE SWITCH
11. ELEVATION FRICTION SCREW

Figure 2–28. Location of Switches and Adjustments on Pedestal Sighting Station.

One or both of the sky filters are pulled down to avoid glare.

By moving the two handles on the yoke sighting station, the two handwheels on the pedestal sight, or the two control grips on the hemisphere sight, the sighting station is moved in elevation or azimuth. Unless the action switch (2) is held down, the turret guns will not follow the sight.

The guns are now ready for tracking and shooting. On the yoke sight, the target-size knob, the range grip, and a single trigger (operated by the right index finger) are used. On the pedestal sight, the target-size knob, the range wheel, and the triggers (pressed by the thumbs) are used. On the hemisphere sight, the target-size knob, the range grip, and the firing trigger are used. The sighting stations also have a push-to-talk button for the interphone.

Gunfire Interruptions. The following paragraphs list the fire interruptions designed to protect the airplane and its gunner from damage by its own guns.

Each upper and lower turret contains a fire-interrupter which automatically interrupts gunfire when the guns are trained at any portion of the airplane.

Each upper and lower turret contains a contour follower which automatically raises or lowers the guns to prevent their hitting any part of the airplane adjacent to the turret. When the guns are raised or lowered by the contour follower, the guns and controlling sight are not in alignment and gunfire is automatically interrupted.

Each turret is provided with an automatic stowing circuit. The turret guns automatically rise or descend to the horizontal position and rotate to the azimuth stow position 11.6 degrees outboard from forward position, when the gunner releases his action switch.

If the sight is raised on the lower turrets or depressed on the upper turrets beyond the limits of gun travel, the guns will remain seated against the stop in elevation and the firing circuit is opened by a limit switch. If the guns and line of sight are more than two or three degrees out of alignment, the firing circuit will be opened by the out-of-synchronism fire interrupter. The guns will follow the azimuth movement of the sight, where not limited by the contour follower, and when the sight and gun are again in alignment, the guns will resume movement in elevation.

Gunner's Preflight Duties

Gun Check. As the guns are not readily accessible during flight they must be in perfect operating condition when installed in the turret. (They should be checked personally by the gunner.)

After it has been determined that the guns have been serviced, the breechblock is removed, and the bore and chamber of the gun barrels are wiped out.

The adjusting screw must be tight against the buffer disks in the backplate.

The guns must be properly lubricated and all excess oil wiped off.

Caution: The bore and chamber should not be oiled before firing as dangerous pressures may develop.

The guns are then installed in the turret. (If the installation is made by others, it should be personally supervised by the gunner.)

The guns must be tight in their mounts.

The gun charges must be securely mounted on the gun.

Operation of the charger and guns should be checked; feeding must be correct; gun heaters should be secure and plugged in; all equipment must be properly safety-wired.

Ammunition and Ammunition Rounds-counter Check. Extreme care should be used in checking ammunition.

Inspection is performed to see that the links on the round are positioned correctly; that the rounds with respect to each other are positioned correctly; that there are no short rounds; that there are no bulges or burrs in the rounds.

All ammunition with too-thick or too-thin extraction rims is removed and replaced with perfect ammunition.

All rounds which have deepset or defective primers must be replaced; rounds should be checked for corrosion; all broken links or improper belting must be replaced; belts are checked by running them through the loading machine.

Ammunition boxes are inspected, and the boxes are loaded, making certain that the rounds point in the correct direction and do not bind.

The body of the cartridge case is oiled before inserting the round into the magazine, in order to prevent jamming. Extreme care should be taken to prevent oil from getting on the primer of the cartridge case.

Caution: Ammunition must not be fed into the feeder mechanism until the system has been checked.

The ammunition rounds-counter on the sighting station control panel should be checked to see that it is in proper working order; it must be set for the total number of rounds to be carried on next mission.

System Check. The remote-control turret system is given a preflight check, to see that everything is in readiness and operating prop-

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erly for the combat mission. (This inspection is virtually a duplication of that which is made by the ground maintenance crew.) The guns and sight should point in the same direction. If the computer does not operate properly in the ground operational preflight check, the computer should be replaced with one which is operating properly.

Miscellaneous Check. The interphone and suit-heater are checked.

Blisters of the yoke and pedestal sights, the window in the hemisphere sight, the sight reflector, mirror, and sky filters on the yoke and pedestal sights must be clean.

Both filaments of the reticle lamp should burn.

Ring-and-bead sight must function properly on the yoke and pedestal sights.

Friction adjustment on the sight is made and the sight stowed preparatory to take-off.

A check is made to see that the parachute is in good condition, and the harness adjusted so that it fits properly.

Spare fuses and tubes should be readily available.

All escape hatches must be cleared of obstructions and made ready for instant use.

A check is made to see that the cabin pressure valves are working properly, and that fire extinguishers, first-aid kit, hand axes, and flashlights are handy.

Ammunition Check. The total of the ammunition "rounds-counter" on the control panel is checked after every three or four bursts in order to gauge and conserve ammunition for the duration of time spent in the combat zone.

Gunner's Prelanding Instructions. The turret is stowed by releasing the action switch; the uni-switch is turned to "off" position.

The sight is stowed in azimuth and elevation, and covered.

All switches on the control panel are turned to "off" position before landing.

After Landing. No one should be allowed to pass in front of the guns until they are unloaded.

Warning: A check is made to see that the last round has been removed from the chamber.

The ammunition boxes are emptied, all ammunition is removed from the airplane, and taken to the armament section.

Any malfunction of the remote-control turret system should be reported to the R.C.T. specialist, who in turn will analyze and report all malfunctions to the ground maintenance crew. The R.C.T. specialist should keep a record of the status of the equipment including malfunctions, shortages of spare parts, etc., and will also note the time and kind of repairs and any other changes made. This log must be kept. Malfunctions of the airplane equipment, trouble lamps, etc., should be reported to flight engineer for repairs.

Gunner's General Information

How to Track an Enemy Plane. If the computer is supplied with the right information, it will come up with the right deflection. If the gunner makes a mistake, the computer will give the wrong answer and the target will be missed. Tracking and framing of the target must be absolutely accurate. Accuracy can be attained only through constant practice.

These rules should be followed closely.

The body, especially the upper arms from elbow to shoulder, must be well braced. A steady hand must be kept on the sight, yet there must be absolute freedom of movement for the wrists and fingers.

The friction adjustments are used to give the sight just the right "touch." The correct setting will vary with the individual gunner. If the adjustment is a little bit tighter or a little bit looser, he will have difficulty in tracking smoothly. If the gunner wears gloves in combat, he should wear them while making the adjustment. The feel of the sight is far different to a gloved hand.

For glare conditions, as little sky filter as possible should be used. The rheostat should be turned all the way with just enough filter to make the reticle clearly visible.

The eyes should be kept a few inches behind the optic head. As the gunner looks through

the glass with one eye, the other eye should be kept open to help in scanning.

The gunner should learn to recognize fighters at a glance and to recall their wing span quickly. When an enemy is sighted, the target-size knob is turned until the proper wing span figure is visible in the upper right corner of the reticle. The center dot of the reticle is placed on the target and the range wheel turned or gripped smoothly to keep the fighter's wingtips barely framed by the reticle circle. A smooth, steady, easy motion will keep the circle the right size at every instant. The range figure, in hundreds of feet, appears in the lower left corner of the reticle.

Note: If the target is viewed from the side, it should be remembered that on most fighters the fuselage is shorter than the wingspan. The target-size knob is set to the fuselage length, or, if the wingspan setting is used, the circle is kept a little beyond the ends of the fuselage.

The center dot of the reticle sight is kept on the middle of the fighter and tracking is smooth and continuous. Once the gunner has started tracking, his grip on the hand wheels or grips should not be changed until the fighter is hit or flies out of view. If the aim is wrong, if the dot is not moved along with the target or goes past him, the dot should be moved back slowly—not jerked. The guns should not be fired while the aim is incorrect.

Avoiding Overheated Guns. Since the opening range of machine guns on the B-36 is so great, there is always the danger that the gunner may fire so many rounds during a single attack that the guns will be overheated and will fire after the triggers are released. Special care must be taken to avoid such overheating which endangers the gunner's own bomber and all the other bombers in the formation. The guns should be cooled at every opportunity. Whenever as many as fifty rounds are fired within a short period, the first possible chance must be taken to cool the guns during a lull in the fighting. The best means for effective, even, cooling of the barrels is to move them right out into the slipstream, pointed fore and aft and at a 30-degree angle from horizontal. Care should be taken, however, not to point them at another bomber. They should be cooled, and the turret retracted for ten full minutes, if there is time.

Runaway Gun. A "runaway" gun should be pointed away from the gunner's own plane and all other bombers in the formation—a straight-up or down position is safest. The gun safety switch then is removed from the "fire" position. This should stop the gun unless it is overheated. If it doesn't, the switch should be thrown back to "fire" to keep the other gun ready for action and to let the bad gun run out.

Power Breaker Buttons. The power breaker buttons on the control panels operate somewhat like fuses. When a circuit is overloaded or overheated, the breaker opens and cuts off the current. A possible indication that circuit breaker CB-2, which is located on the control panel, has opened is to see the turret-extended light, also located on the control panel, and the sight reticle light go out while the system is operating. If the firing trigger is depressed for firing and neither one of the rounds counters operates, circuit breaker CB-3 may be open. To reset the breaker and start the circuit working again, the uni-switch on the control panel is turned off and the "breaker buttons pushed hard. The uni-switch is turned back to its former position and the sequence repeated, if necessary, until the turret properly follows the sight. After the uni-switch is back in its operation position, an interval of ninety seconds is required for the thyratron controller to restore DC power to the circuit.

Avoiding Self-inflicted Damage. Self-inflicted damage, which means bullet holes in one of our own planes from one of our guns, is always a possible danger when bombers fly in formation. Every precaution should be taken to avoid it.

Warning: If there is a choice between letting an enemy fighter go and running the risk of firing into a friendly bomber, the fighter should be allowed to escape.

There are no hard and fast rules for avoiding self-inflicted damage. The main consideration is to understand what happens to the guns when they are being sighted, and to exercise good judgment based on that knowledge.

As the sight is held on an attacking plane, the computer sets in deflections very similar to those used in position firing. The maximum deflection which the B-36 computers can set is about 200 mils, or more than 11 degrees. (A mil is the angle formed by two intersecting lines which are one foot apart at 1,000 feet.)

A very large deflection will also be obtained when firing at a beam attack. To avoid this, a safety zone is allowed for every bomber in the formation. As soon as the sight gets into this zone, the gunner should take his finger off the trigger.

SECTION II—TURRETS—UPPER, LOWER, AND NOSE

1. INTRODUCTION

This section contains instructions for the overhaul of the upper, the lower, and the nose turrets, of the remote-control turret system in the B-36 airplane.

The instructions for the overhaul of the tail turret are contained in a separate handbook. The instructions in both turret handbooks form a part of the complete instructions issued for the operation, service, and overhaul of the B-36 remote-control turret system.

The elevation and azimuth movement, the overall dimensions, and the weights of the different turrets used in the B-36 remote-control turret system are given in Table I.

2. GENERAL DESCRIPTION

There are eight turrets in the remote-control turret system of the B-36: four upper turrets, two lower turrets, one nose turret, and one tail turret. The tail-turret overhaul instructions are contained in a separate handbook.

All the upper and the lower turrets are retractable into the airplane's fuselage, a feature which reduces drag (Figures 2-2, 2-4, and 2-6). A fire interrupter which prevents the possibility of damage inflicted by the airplane's own guns, and a contour follower which prevents the possibility of the guns striking against the fuselage as the guns are swung along the contour, are installed in each of the upper and the lower turrets. The nose turret, because of its location in the airplane, is not retractable and is not equipped with a fire interrupter or a contour follower.

Each turret is equipped with two 20-mm machine guns which are mounted on a saddle assembly which is, in turn, mounted in the inner ring of the turret ring assembly. This mounting arrangement makes it possible to move the guns into any elevation and azimuth position within the limits imposed by the design of the armament system of the airplane.

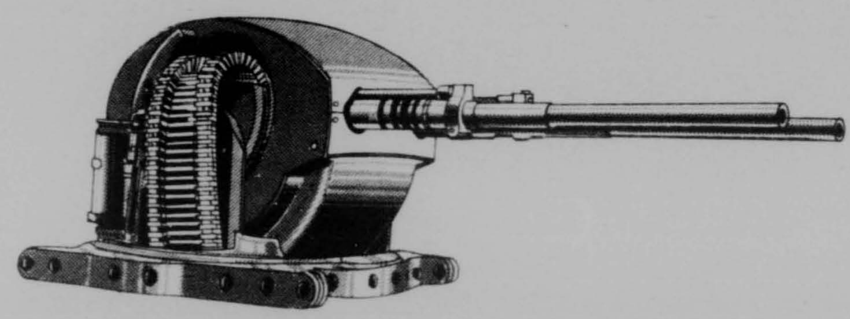

Figure 2–29. Front View of Upper Turret with Dome Removed.

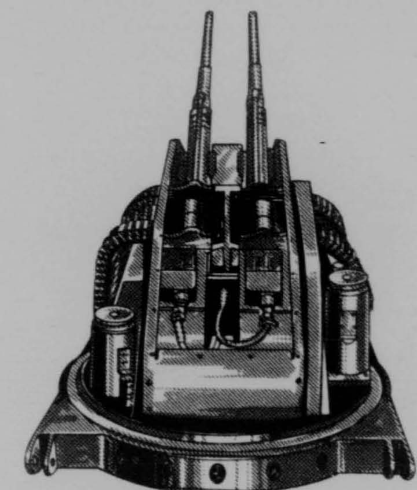

Figure 2–30. Rear View of Upper Turret with Dome and Top Panel of Gun Enclosure Removed.

The ammunition for all turret guns is carried in ammunition boxes which are attached to the airplane's structure. A separate ammunition box is provided for each gun and the rounds of ammunition, which are linked together to form a belt, are fed to the gun through flexible ammunition chutes. An ammunition booster on each box and a feed mechanism on each gun insure a positive feed of the ammunition to the gun. The ejected ammunition cases and links are collected from the guns of the upper turrets and the nose turret. The cases and links from the lower-turret guns are ejected through the lower dome assemblies into the slipstream of the airplane.

Upper Turrets

The four upper turrets are the same, except for their contour followers, their fire interrupters, their gun chargers, and their case-and-link ejection chutes (Figures 2-29 and 2-30). The basic assemblies which make up each upper turret are described in detail in the following paragraphs.

Inner and Outer Ring Assembly. This assembly is the basic framework of the turret. The outer ring is supported and positioned in the airplane by two fixed supports in the airplane's structure and by two movable supports of the retraction mechanism. The inner ring is positioned to the outer ring by ring bearings. It supports the saddle and the azimuth and elevation drives.

Outer Ring. The outer ring assembly consists of a single casting upon which the rest of the turret proper is supported (Figure 2-31). The azimuth ring gear (2), bolted to the outer ring, helps position the lower ring bearing, which in turn positions the inner ring (3).

Ring Bearings. The two ring bearings are located between the inner and outer rings. They support and position the inner ring in the outer ring.

Inner Ring and Saddle Supports. The inner ring (Figure 2-32) and saddle supports (1 and 2) are two magnesium castings bolted together. The base of the inner ring and saddle support assembly forms the inner ring or housing. It is held in place by the ring bearings. The two saddle supports extend upward from the inner ring. The azimuth drive assem-

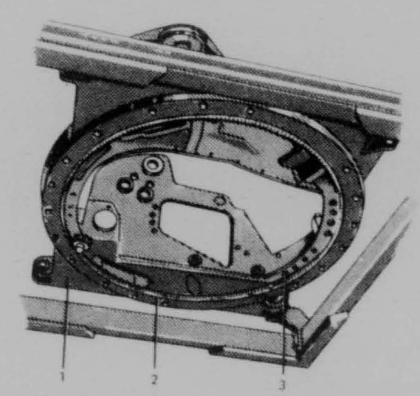

Figure 2–31. Bottom View of Inner and Outer Ring Assembly (Shown in Fixture)—Upper Turrets.

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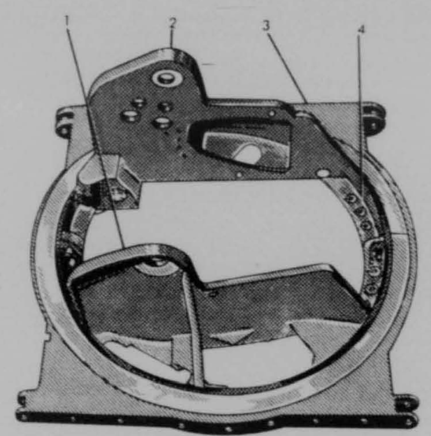
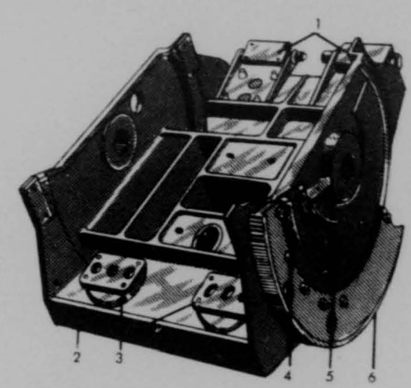


1. SADDLE SUPPORT
2. SADDLE SUPPORT
3. OUTER RING
4. INNER RING

Figure 2—32. Top View of Inner and Outer Ring Assembly—Upper Turrets.



1. FRONT GUN SUPPORTS
2. SADDLE
3. REAR GUN SUPPORTS
4. STOP
5. LIMIT SWITCH CAM
6. ELEVATION GEAR SECTOR

Figure 2—33. Saddle, Sector, and Bracket Assembly.

bly is mounted on the left-hand saddle support. The elevation drive assembly and the contour follower are mounted on the right-hand saddle support.

Trunnions. Two steel trunnions, used to support the saddle, are bolted to the saddle supports. Needle bearings, pressed into the saddle, rotate with the saddle around the trunnion.

Azimuth Stops. The azimuth stops and limit-switch actuators are mounted on the outer ring. The azimuth limit-switches and buffer cartridge are mounted on the inner ring. These parts limit the azimuth travel of the turret to 200 degrees with 1½ degrees overtravel at each end.

Saddle, Sector, and Bracket Assembly. The saddle, sector, and bracket assembly (Figure 2-33) supported between the two saddle supports, mounts the two 20-mm guns. The guns are elevated or depressed by the elevation drive which engages the gear sector attached to the right-hand side of the saddle assembly.

Saddle. The saddle is a magnesium casting on which the other parts of the saddle, sector and bracket assembly are mounted.

Elevation Gear Sector. The gear sector (6) is bolted and doweled to the saddle. The elevation drive pinion meshes with the gear sector which moves the saddle and guns in elevation.

Gun Supports. The two 20-mm guns are mounted on the saddle by front and rear gun supports. Both front and rear gun supports are adjustable to provide for alignment of the gun bore. The two front gun supports (1) bolted to the saddle can be adjusted to move the guns laterally. The two rear gun supports (3) fastened to brackets which in turn are bolted to the rear of the saddle, can be adjusted to move the guns vertically.

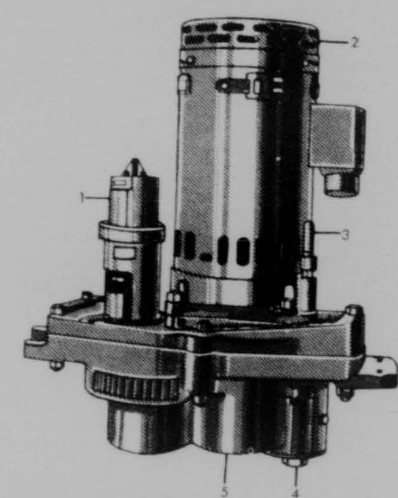
Elevation Stop and Limit-switch Cam. The elevation stop (4) and the limit-switch cam are mounted on the saddle. The limit-switch cam operates the elevation limit switch when the guns have reached their maximum elevation of approximately 90 degrees and an overtravel of 1½ degrees. The elevation stop mechanically restricts the travel of the guns at zenith after the limit-switch cam has been operated.

Azimuth Drive Assembly

The azimuth drive assembly (Figure 2-34)

which is located on the left saddle support of the inner ring assembly, performs two functions: it supplies the mechanical power required to drive the turret and guns in azimuth; and it contains the electrical equipment which assists in controlling the azimuth position of the guns. The drive assembly consists of three main sub-assemblies: the drive motor (2), the speed-reduction gear assembly (5), and the tandem Selsyn assembly (1).

Drive Motor. The azimuth drive motor (2), rated 1.1 horsepower, is a "separately excited" motor which rotates either clockwise or counterclockwise according to the signal from the thyratron controller. The input voltage from the thyratron controller regulates the motor speed. A solenoid-operated brake located at the base of the motor prevents rotation of the motor armature (and, consequently, the turret) when the motor is not energized. When the sight moves beyond the azimuth limit of the guns, the brake solenoid is de-energized and the brake is applied, holding the turret against the limit stop. When the sight is again moved within the limits of



1. TANDEM SELSYN ASSEMBLY
2. MOTOR
3. BRAKE RELEASE LEVER
4. CRANK ADAPTER
5. GEAR ASSEMBLY

Figure 2—34. Azimuth Drive Assembly.

gun travel, the solenoid becomes energized and releases the brake. The brake can be released manually by two spring-loaded levers, one located on each side of the motor.

Gear Assembly. The bear train of the azimuth drive assembly provides the speed reduction necessary to drive the turret in azimuth and to rotate the tandem Selsyn rotors. The gear assembly is driven through a friction clutch which protects the gear train from excessive shocks when the guns reach their maximum azimuth limit.

Power Gearing. Power to drive the turret in azimuth is transmitted from the motor through the gear train of the azimuth drive assembly as follows: The motor pinion (8) (Figure 2-35) meshes with the large gear of the clutch and gears assembly (5) which drives, through two speed-reduction gear stages (14 and 15) the azimuth drive gear (13) which in turn meshes with the azimuth ring gear (12) on the turret outer ring assembly. The turret is driven in either direction, clockwise or counterclockwise, depending upon the direction of rotation of the drive motor.

Selsyn Rotor Position Gearing. The tandem Selsyn control transformer assembly, which is mounted on the azimuth drive assembly, embodies both the 1-speed and the 31-speed Selsyn units with an internal planetary reduction gear system interposed between them. The Selsyn gear (11) on the end of the 31-speed rotor shaft meshes with the Selsyn drive gear (10) on the azimuth drive-gear shaft. As the name implies the 31-speed Selsyn rotor is geared to turn at a speed 31 times that of the turret. That is, if the turret were to turn one complete revolution, the 31-speed Selsyn rotor would turn 31 revolutions. The 1-speed Selsyn unit, which is in tandem with the 31-speed Selsyn unit, is driven through the interposed planetary gear system by the 31-speed Selsyn rotor shaft. The speed ratio of the planetary reduction gear system is 31 to 1. Thus the 1-speed Selsyn rotor turns at the same speed as the turret. The tandem Selsyn control transformer assembly indicates by means of an electric control signal, the azimuth position of the line of sight.

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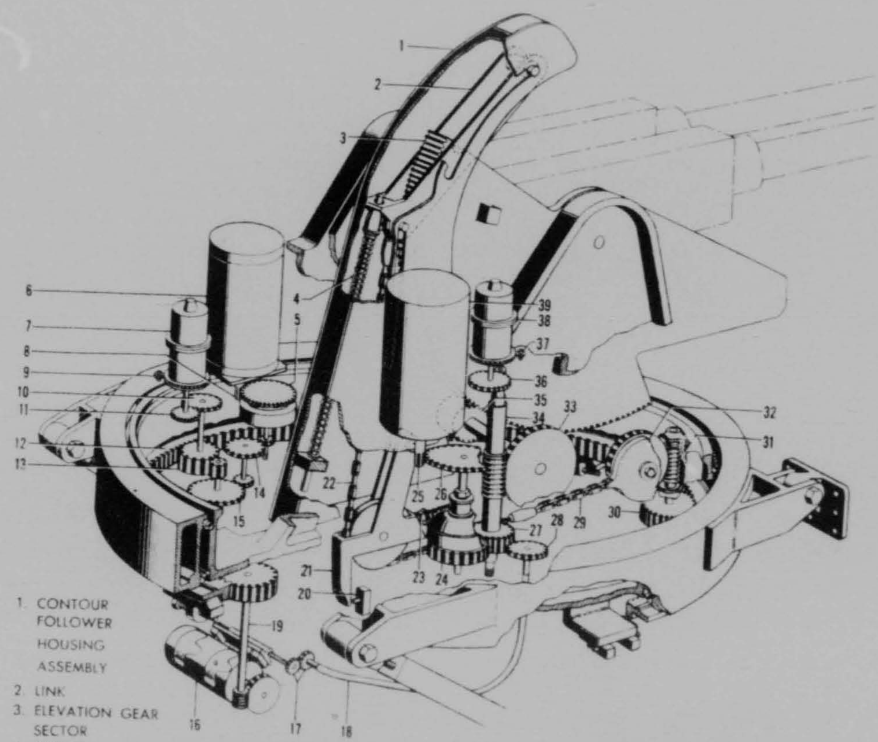


1. CONTOUR FOLLOWER HOUSING ASSEMBLY
2. LINK
3. ELEVATION GEAR SECTOR
4. SPRING
5. CLUTCH AND GEARS ASSEMBLY
6. AZIMUTH DRIVE MOTOR
7. TANDEM SELSYN UNIT (CONTROL TRANSFORMERS)
8. MOTOR PINION
9. SELSYN ADJUSTING PINION
10. SELSYN DRIVE GEAR
11. SELSYN GEAR
12. AZIMUTH RING GEAR
13. AZIMUTH DRIVE GEAR
14. SPEED REDUCTION GEARS
15. SPEED REDUCTION GEARS
16. INTERRUPTER ASSEMBLY
17. ELEVATION GEAR ASSEMBLY
18. FLEXIBLE CABLE
19. AZIMUTH GEAR ASSEMBLY
20. LIMIT SWITCH
21. ROLLER-AND-BRACKET ASSEMBLY
22. CHAIN
23. ADJUSTMENT SCREW AND SPRING
24. CLUTCH ASSEMBLY
25. MOTOR PINION
26. GEAR
27. WORM SHAFT GEAR
28. GEAR AND SHAFT ASSEMBLY
29. CHAIN
30. PINION
31. WORM
32. WORM WHEEL CAM AND CHAIN ASSEMBLY
33. WORM WHEEL
34. WORM SHAFT
35. SHAFT GEAR
36. SELSYN GEAR
37. SELSYN ADJUSTING PINION
38. TANDEM SELSYN UNIT (CONTROL TRANSFORMERS)
39. ELEVATION DRIVE MOTOR

Figure 2–35. Schematic Mechanical Diagram of Upper Turret Gear System.

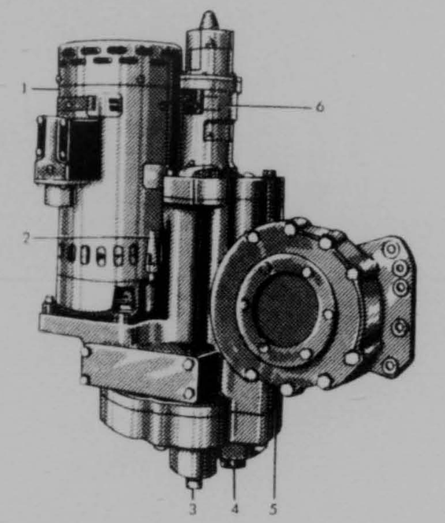
Manual Azimuth Movement. A handcrank is provided with each turret for manual rotation of the turret. A crank adapter (Figure 2-34) is provided on the bottom of the gear unit of the azimuth drive assembly for insertion of the handcrank. The crank engages the splined end of the clutch-and-gears-assembly shaft in the gear unit. Before the turret can be rotated, the brake in the drive motor must be released by means of the brake release levers (3). Approximately 70 revolutions of the handcrank are required to rotate the turret through its complete azimuth travel of 200 degrees.

Elevation Drive Assembly

The elevation drive assembly (Figure 2-36) which is located on the right saddle support of the inner ring assembly, performs three functions. It supplies the mechanical power required to drive the saddle and guns in elevation; it contains the electrical equipment which assists in controlling the elevation position of the guns; and it provides the gear drive for introducing the elevation position of the guns into the fire interrupter assembly. The drive assembly consists of three main sub-assemblies—the drive motor (1), the speed-reduction gear assembly (5), and the tandem Selsyn assembly (6).

Gear Assembly. The gear train of the elevation drive assembly provides the speed reduction necessary to drive the saddle and guns in elevation to rotate the tandem Selsyn rotors, and to drive the elevation functions of the fire interrupter assembly. The gear assembly is driven through a friction clutch which protects the gear train from excessive shocks when the guns reach their maximum position of elevation or depression.

Power Gearing. Power to drive the saddle and guns in elevation is transmitted from the motor through the gear train of the elevation drive assembly as follows: The motor pinion (25) (Figure 2-35) meshes with the large gear (26) on the clutch assembly shaft. The clutch assembly gear (24) meshes with the gear (27) on the end of the worm shaft (34). The worm meshes with the worm wheel (33) on the elevation drive shaft and drives the shaft gear (35) which meshes with the elevation gear sector (3) on the saddle. The saddle



1. MOTOR
2. BRAKE RELEASE LEVER
3. COUPLING FLANGE (FIRE INTERRUPTER CABLE)
4. CRANK ADAPTER
5. GEAR HOUSING
6. TANDEM SELSYNS

Figure 2–36. Elevation Drive Assembly.

and guns are driven either up or down, depending upon the direction of rotation of the drive motor.

Selsyn Rotor Position Gearing. The tandem Selsyn control transformer assembly used on the elevation drive assembly is the same as that used on the azimuth drive assembly (Figure 2-35). The Selsyn gear (36) on the end of the 31-speed rotor shaft meshes with a small gear on the end of the worm shaft (34).

Fire Interrupter Drive

An indication of both the azimuth and the elevation position of the guns is necessary in the operation of the fire interrupter assembly. The elevation indication is obtained from the elevation drive assembly and is transmitted by a flexible cable to the fire-interrupter assembly. The fire-interrupter take-off gearing in the elevation drive assembly consists of the gear and shaft assembly (28) whose gear meshes with and is driven by the wormshaft gear (27). One end of the gear-and-shaft-as-

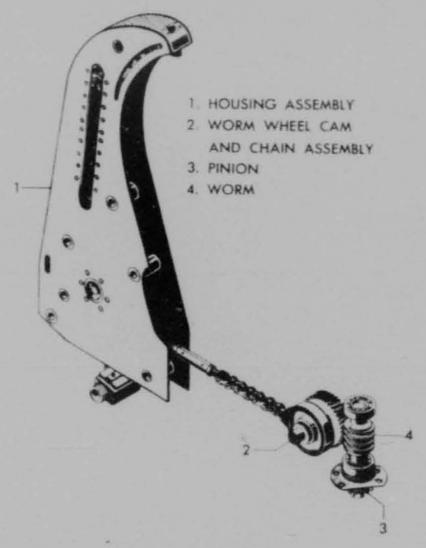


Figure 2–37. Contour Follower.

sembly shaft has external splines which mate with the splined fittings on the flexible cable (18) which drives the interrupter (16). The splined end of the shaft is enclosed by the coupling flange (Figure 2-36) which is externally threaded to receive the connector of the flexible cable. Since the gear and shaft assembly is geared to the power gear train in the elevation drive assembly, its position is relative to the elevation position of the saddle and guns. It is this position indication which is transmitted to the fire interrupter.

Manual Elevation Movement. A crank adapter (4) (Figure 2-36) is provided on the bottom of the gear unit of the elevation drive assembly for the insertion of the handcrank which is provided with each turret. The crank engages the splined end of the worm shaft in the gear unit. Before the saddle and guns can be raised or lowered, the brake in the drive motor must be released by means of the brake release levers. Approximately sixty-two revolutions of the handcrank are required to move the saddle and guns through their complete elevation travel.

Contour Follower

A contour follower (Figure 2-37) assembly is used on each of the upper and the lower retractable turrets. The only difference among the several turret contour followers is in their contour pattern. The contour pattern can be adjusted so that any contour-follower assembly can be used with any turret.

The function of the contour follower is to limit the downward travel of the guns (for upper turrets), or the upward travel (for lower turrets), for all azimuth positions of the turret, in order to prevent the guns from hitting the airplane fairing as the guns are swung along the fuselage contour, and to prevent the guns from pointing at the gunner's combat station.

The contour-follower assembly is mounted on the inner ring of the turret and consists of the following component parts and assemblies: housing assembly (1) (Figure 2-35), worm wheel cam and chain assembly (32), worm (31), and pinion (30).

The housing assembly is mounted on the right-hand saddle support in the path of the elevation-gear sector which travels between the two side plates of the housing. It consists of the link (2) and chain (22) assembly, roller and bracket assembly (21), spring (4), adjustment screw and spring (23), and two limit switches.

The upper end of the link rides in a curved track whose center of radius is that of the trunnion which supports the saddle. The lower end of the link rides in a straight track and is connected by a chain which passes over the roller of the roller-and-bracket assembly, to the worm wheel cam and chain assembly.

The roller-and-bracket assembly is pivoted at one end in the lower part of the housing. The other end of the roller-and-bracket assembly is held in position against the adjustment screw and spring by the chain which connects the link to the worm wheel cam and chain assembly. The chain is kept taut by the spring which pushes against the link to keep the whole contour follower linkage snug at all times.

The adjustment screw and spring is mounted between the two side plates in the lower

part of the housing and serves as a mechanical stop beyond which the upper turret guns can depress, or the lower turret guns can elevate, only as permitted by the stretch in the chain or the compression of the spring. The total movement of the roller and bracket assembly is limited to approximately 3/16 inch by the adjustment screw and spring before the spring bottoms.

There are two limit switches. One switch is attached to the upper end of the gear sector and the other is mounted under the adjustment screw and spring. The two switches are wired in series. When either switch is actuated, a relay in the turret junction box is energized which connects a plugging circuit (reverse current) into both turret-drive motors. The relay then cuts off both elevation and azimuth drive motors in the direction they are rotating, sets their brakes and cuts off the firing circuit. The upper switch acts to stop motion of the turret before a dangerous stress is brought upon the contour-follower chain. The upper switch is actuated by a cam and follower mechanism, located between the upper end of the gear sector and the link of the contour follower, to provide for stopping the motor 1½ degrees of elevation travel before contact is made with the contour-follower link. If the upper switch should fail to operate, the lower switch serves as a safeguard against damage to the equipment. The lower switch is actuated by an actuator arm assembly on the roller bracket when the adjustment screw and spring starts to compress.

Worm-wheel Cam-and-chain Assembly, Worm and Pinion. As the turret is rotated in azimuth, the pinion (30) which meshes with the azimuth ring gear (12) is rotated, turning the worm (31) which rotates the worm-wheel cam of the worm-wheel cam-and-chain assembly (32). As the worm-wheel cam is rotated, the chain is pulled in and around the cam, and in turn the link (2) is pulled down in its track. Thus the link moves up and down in its track as the turret moves in azimuth. The amount of up-and-down movement is determined by the diameter of the cam. If the motion of the link is plotted against the azimuth travel of the turret, measurement being taken in mils, the resulting curve represents the lower elevation limit for upper turrets, and upper elevation limit for lower turrets. The curve can be raised or lowered by setting the length of the chain by means of the turnbuckle. Since the diameter of the cam is fixed, the shape of the curve cannot be changed; the curve can be only raised or lowered by the chain setting.

Thus the different limits of gun elevation position are governed by the azimuth position of the turret as follows: As the turret is rotated in azimuth, the position of the link in its track is changed. When the guns are depressed (upper turrets) or elevated (lower turrets) to a position 1½ degrees before the gear sector engages the link, the upper limit switch is actuated. When the upper limit switch is actuated, the circuits to the azimuth and elevation-drive motors are plugged (reverse current is applied) in the direction they are rotating, the motor brakes are set, and the circuits to the guns are cut off. Although the limit switch cuts off all these circuits, there is a backout circuit for both the azimuth and the elevation drives which pulls the guns back off the contour as soon as the sight returns to the area of fire. The guns step-follow the contour when going either up or down the contour pattern. If the upper limit switch should fail to operate, the guns will continue to travel until the elevation-gear sector pushes against the link. This will cause the chain to tighten and force the roller and bracket assembly against the adjustment screw and spring. A small movement of the roller and bracket assembly will actuate the lower limit switch which has the same function as the upper limit switch.

Interrupter Assembly

The interrupter assembly prevents damage to the airplane by its own guns (Figure 2-38), indicates when the turret is stowed, and supplies an azimuth-position signal (forward or aft) to the thyratron controller. The interrupter assembly is mounted on the inner ring and consists of a housing (1) (Figure 2-39), a drum assembly (8), a switch carriage (13), and a position switch (10). Five bolts through the flange on the housing of the interrupter attach it to the inner ring.

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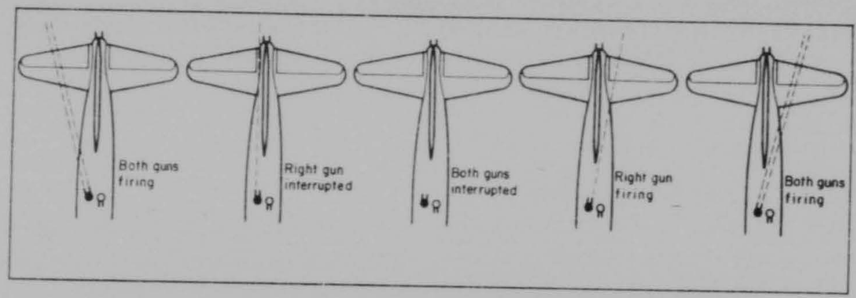
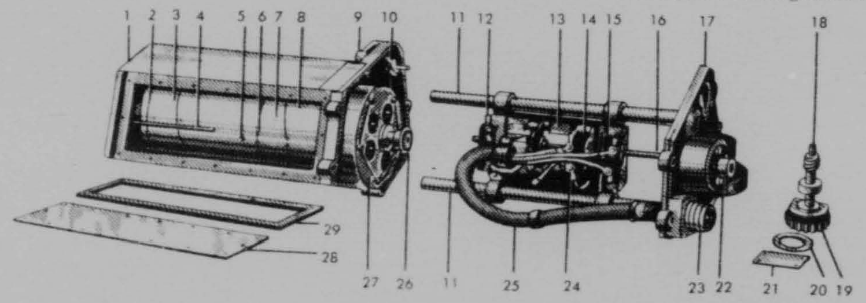


Figure 2—38. Fire Interrupter Protects Airplane from its Own Guns.

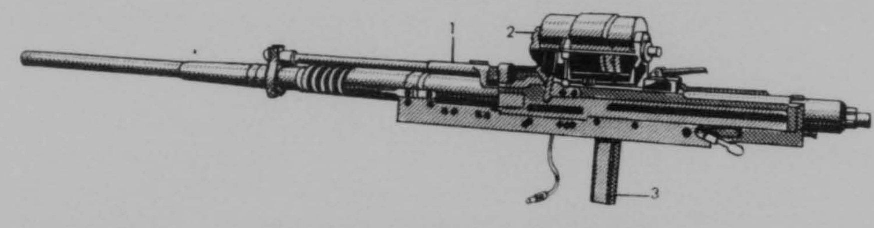
Housing. All parts of the interrupter are attached to or assembled inside of the housing (1). Bearings in the housing and in the cover plate (17), attached to the end of the housing, position the drum. There are two small gear assemblies on the cover plate for azimuth and elevation positioning.

Drum Assembly. The drum assembly consists of a cylindrical drum to which is fastened two sets of stainless-steel cam patterns (3 and 7) (Figure 2-39), a stow button (6), and two end plates (2 and 27). One end plate (27) serves as a cam for indicating the azimuth position. The drum assembly is geared to the azimuth gear assembly (19, Figure 2-35) on the housing cover. The azimuth gear assembly, in turn, meshes with the azimuth ring gear (12) on the outer ring of the turret. The stow button operates a switch which turns on a light in the control panel in the gunner's



1. HOUSING ASSEMBLY
2. END PLATE
3. CAM PATTERN
4. GUIDE ROD
5. ZEROING HOLE
6. STOW BUTTON
7. CAM PATTERN
8. DRUM
9. POSITION SWITCH CONNECTOR RECEPTACLE
10. POSITION SWITCH (AZIMUTH INDICATION)
11. GUIDE ROD
12. LIMIT SWITCH
13. SWITCH CARRIAGE
14. STOW SWITCH
15. LIMIT SWITCH
16. LEAD SCREW
17. COVER ASSEMBLY
18. WORM SHAFT-AZIMUTH DRIVE
19. AZIMUTH DRIVE GEAR
20. SHIM
21. POSITION SWITCH ACCESS COVER
22. ELEVATION DRIVE SPLINE AND ADAPTER
23. CARRIAGE SWITCHES CONNECTOR RECEPTACLE
24. ZEROING PIN AND HANDLE ASSEMBLY
25. TUBING
26. WORM GEAR-AZIMUTH DRIVE
27. END PLATE (WITH CAM)
28. COVER PLATE (PLEXIGLASS)
29. SPACER

Figure 2—39. Interrupter Assembly Partially Disassembled.



1. GUN 2. FEED MECHANISM (M-3) 3. LINK EJECTION CHUTE

Figure 2—40. 20-mm Machine Gun, Showing Feed Mechanism and Link Ejection Chute.

compartment when the turret is stowed and ready for retraction. There is one set of cam patterns for each gun. This set of patterns represents such areas as propellers, wing tips, etc., for which fire must be interrupted. To insure greater interrupter accuracy, the drum assembly rotates 1.714286 times as fast as the inner ring on the turret.

Switch Carriage Assembly. The switch carriage (13, Figure 2-39) contains three snap-action switches (12, 14, and 15). Two of the switches, one for each gun, are normally closed; and one for the stowed position is normally open. The switch carriage is mounted on two rods (11) which guide the carriage back and forth across the drum assembly. The carriage is driven by a long lead screw (16), turned by the elevation gear assembly (17, Figure 2-35) on the housing cover. The gear assembly is driven by a flexible cable (18) whose other end is connected to the gear and shaft assembly (28) of the elevation drive assembly. Thus, elevation position of the guns is transmitted to the switch carriage with respect to the drum assembly. The switch carriage also contains a zeroing pin (24) (Figure 2-39) used to time the interrupter assembly (both in azimuth and elevation as regards the guns). The zeroing pin in the carriage should line up with the zeroing hole (5) in the drum when the guns are at zero degrees elevation and the turret is at zero degrees azimuth.

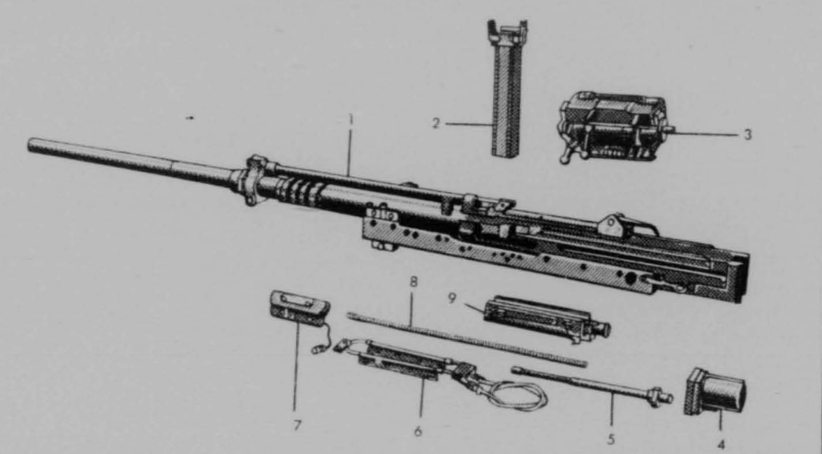
Position Switch. The position switch (10) (Figure 2-39), mounted on the housing and actuated by the drum end plate (27) nearest the housing cover, is a three-terminal, snap-action switch. It is closed either to one or to the other of two circuits, depending upon which side of broadside (forward or aft) the guns are pointing. This is necessary in order to have step-contouring of the guns in both up and down directions.

20-mm Guns and Accessories

The 20-mm automatic gun (Figure 2-40) is a combination blow-back and gas-operated aircraft weapon. The gun is air-cooled and has a cyclic rate of fire from 750 to 850 rounds per minute. The gun may be fired from either the left or right side, depending on the mounting of the feed mechanism (2). The breech block assembly is drawn back for injection of the first round by an automatic, electrically operated gun charger. The charger also ejects the duds. A rounds-counter actuator is included in the charger. Each gun contains a gun heater to prevent freezing of the gun. The gun accessories also include an electric trigger and a link chute.

Feed Mechanism. The 20-mm gun feed mechanism (2), mounted on top of the gun, is a complete unit designed for feeding belted ammunition into the 20-mm automatic gun. There are two feeders—one feeds ammunition from the right-hand side. Either the left hand or the right hand side feeder is used, depending upon the side from which the gun is fed. The main functions of this mechanism are to bring the ammunition from the ammunition chute into the gun, to strip the links from the ammunition belt, and to position the rounds, one at a time, into the mouth of the gun so that they can be carried forward into the chamber by the breechblock bolt.

Gun Accessories. The gun accessories in-



1. GUN
2. LINK EJECTION CHUTE
3. FEED MECHANISM
4. BUFFER SPRING HOUSING
5. DRIVE SPRING GUIDE
6. HEATER
7. ELECTRIC TRIGGER
8. DRIVE SPRING
9. BREECH BLOCK ASSEMBLY

Figure 2–41. 20-mm Machine Gun Partially Disassembled.

clude the following: gun charger, gun heater (Figure 2-41), electric trigger (7), link ejection chute (2), and gun-mounting brackets.

Gun Charger. The gun charger draws the bolt back to allow the first round to be positioned in the chamber. It also clears the gun of defective ammunition in case of misfire and cocks the gun after ejecting the duds.

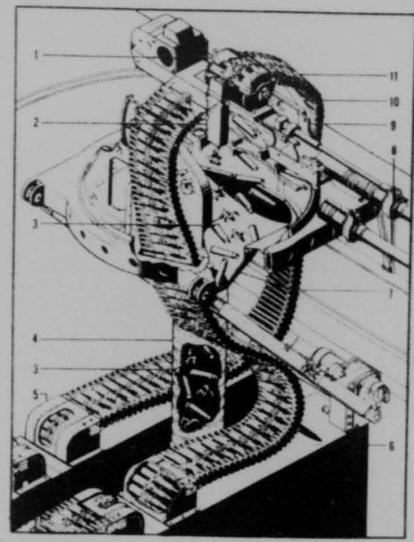
Gun Heater. The gun heater (Figure 2-41) attached to each side of the gun receiver where the cases are ejected, consists of a resistance coil assembly. It furnishes heat to the working parts of the guns to prevent freezing at low temperatures. The gun heater is government-furnished equipment.

Electric Trigger. The electric trigger (7) operates the gun sear-actuating mechanism.

Link Chute. The link chute (2) is a metal fitting attached to the inboard side of the feed mechanism. It directs the ejected links from the feed mechanism down to an opening in the saddle assembly.

Upper Forward Turret Ejection Chutes

In the upper forward turrets, the case and link-chute adapter (stainless steel) is fastened to the bottom of the inner ring assembly. A rubber fabric chute, which funnels down to a rubber fabric tube, six inches in diameter, is fastened to the adapter. A spiral spring is sewn into the fabric tube to give it rigidity. The tube empties into a canvas bag, located in the airplane fuselage, which holds the ejected cases and links. The end of the tube is held at the top of the case-and-link container by an opening in the cover plate and by a flange and angles attached to the tube. By removing the four ring bolts and pulling away the ring, the case-and-link chute can be thrust through the opening in the plate and the ring reinstalled. The ring will prevent the case-and-link chute from moving up through the hole. After the tube is threaded through the plate, it will normally float in the opening in the plate, with the flange and angles acting



1. FEED MECHANISM
2. LINK EJECTION CHUTE
3. EJECTED LINKS AND CASES
4. LINK AND CASE EJECTION CHUTE
5. AMMUNITION BOOSTER
6. AMMUNITION BOX
7. CHASE CHUTE ADAPTER
8. GUN
9. SADDLE
10. SADDLE SUPPORT
11. AMMUNITION FEED CHUTE

Figure 2–42. Route of Incoming Ammunition and Ejected Cases and Links—Upper Turrets.

as a stop for its travel in the up or down directions. In retracting the turret from firing position, the rubber fabric chute and tube are deformed to allow full retraction. In bringing the turret into firing position again, the coil spring in the tube brings it back to its original shape and position. When cases and links are ejected from the gun and feeder, they fall through openings in the saddle casting, are deflected into the rubber fabric chute by the adapter, flow through the chute into the tube and then fall into a container in the airplane (Figure 2-42).

Upper-aft-turret Ejection Chutes. The upper-aft-turret ejection chute is similar to the upper-forward-turret ejection chute, described in the preceding paragraph, except for the method by which the end of the tube is held above the case-and-link container. The end of the tube is held above the container by tension coil springs which are fastened to the airplane and a flange on the tube end. In retracting the turret from firing position, the rubber fabric chute and tube travel downward between the ammunition boxes until the tension of the coil springs is relieved. Then the chute and tube are deformed to allow full retraction. In bringing the turret into firing position again, the coil spring in the tube brings it back to its original shape while the two external coil springs position it above the canvas bag.

Ammunition Boosters

The 20-mm automatic gun relies on a feeder, which is a component of the gun, to pull rounds of ammunition into the guns as it fires. The pull of the feeder is limited. Excessive retarding pull by a long ammunition belt results in failure of the feeder to supply a succeeding round of ammunition to the gun as it fires. Remote installations of ammunition boxes on the B-36 require boosters to assist the gun feeder and to assure continuous feeding of the ammunition belts. The boosters are installed on the ammunition boxes.

Construction. (Figure 2-43.) The booster consists of a gear unit and a guide bracket. The gear unit consists of the motor (3), gearing, clutch, and ammunition sprockets (1). The guide bracket is a sheet-metal support which serves both as a mount for the drive unit and as a means for directing the ammunition belt over the sprocket on the gear unit. The guide bracket also strips ammunition from the rotating sprocket to prevent jamming.

Gear Unit. (Figure 2-44.) The gear unit is powered by an aircraft electric motor (1) with a three-phase, 208-volt, AC power rating. Rotation of the motor armature is transmitted through a gear train, a clutch (2), and a shock-resisting drive (3) to the ammunition sprockets (4 and 5). The gear train and clutch are enclosed in a housing (2) (Figure 2-43) and a cover (4). The sprocket is supported in bearings between the housing proper and an

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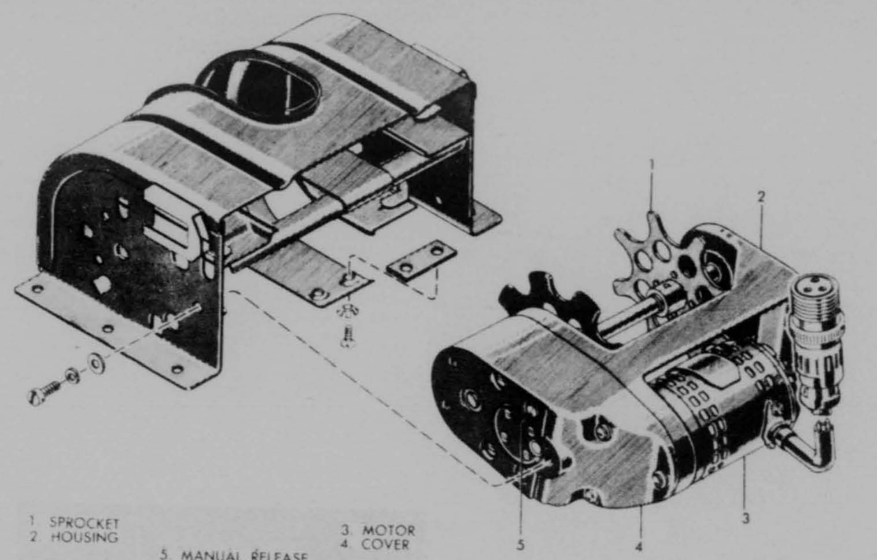

Figure 2–43. Ammunition Booster Assembly Partially Disassembled.

arm extending from the housing. The gear unit clutch has two unusual features: it unloads at a constant torque, and it has free wheeling, if the sprocket is rotated by hand in the direction that the sprocket is driven by the motor. The clutch (Figure 2-45) consists of a driver disk (3), and a clutch gear (6) mounting two rollers (5) in needle bearings (4), spring-loaded clutch arms (2) mounted on a spool (1), and a pinion-shaft assembly

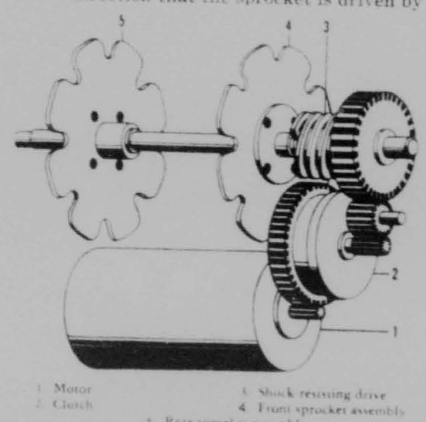

Figure 2–44. Schematic Diagram of Ammunition Booster Gear Train.

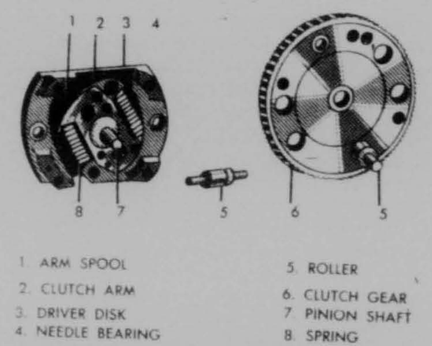

Figure 2–45. Ammunition Booster Clutch Partially Disassembled.

(7). The rollers engage the cams and drive the spool and pinion shaft until a torque is reached where the cams depress their tension spring. When the cams are depressed, the rollers overtravel the cams.

Function. (Figure 2-44.) The booster motor (1) is energized and the sprockets (4 and 5) rotated when the firing circuit is closed. Rotation of the sprockets move the ammunition belt forward until the portion of the belt between the booster and the gun is compressed to a point where torque on the cams and the compression springs in the clutch (2) depress the cams. The rollers then overrun the cams and the sprockets are not rotated. Overrunning of the cams continues until firing of the guns reduces the compression of the ammunition belt to a point where torque permits the rollers and cams to engage and rotate the sprockets. This engaging and disengaging action of the clutch is cushioned by a shock-resisting drive (3) connected between the drive gearing and the sprockets. Sudden loads on the motor and gearing or the sprockets are also cushioned by this spring. Since the normal driving speed of the sprockets is greater than the rate of fire, there will be a series of starts and stops of the sprockets during an extended burst of gunfire. Each time the sprockets stop, the ammunition belt is left in a partially compressed condition ready for the next firing. A ratchet-type brake in the housing of the gear unit maintains the compression during the period the firing circuit is not energized. A manual release (5) (Figure 2-43) on the exterior of the housing may be used to disengage this brake during unloading operations. A special feature of the torque-limiting clutch is that the clutch is disengaged during the periods of high torque. The motor is, therefore, unloaded and motor life is increased. The special clutch design (overrun of the clutch rollers) permits ammunition to be pulled through the booster by the gun in the event that the booster becomes inoperative.

Ammunition Feed Chutes. Ammunition is guided from the booster outlet mouth to the feed mouth by flexible feed chutes. The chute bends enough to allow for azimuth movement of the turret and elevation movement of the guns. In the lower turrets, the feed chutes travel from the booster mouth to the inner ring where guide brackets guide the ammunition belt to the feed mouth.

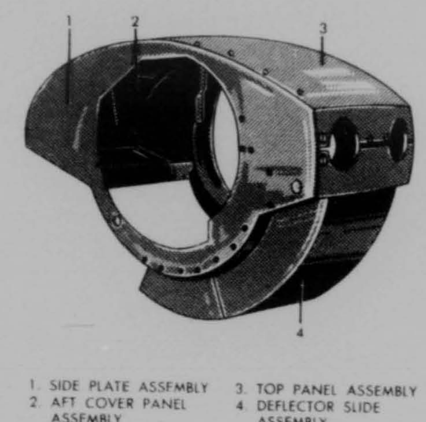

Figure 2–46. Upper Turret Gun Enclosure.

Gun Enclosure. The gun enclosure assembly (Figure 2-46) is made of magnesium alloy, specification No. AN-M-29. The assembly approximates the contour of the dome and is designed to enclose the moving parts of the gun. It consists of three sections: the side-plate assembly (1) which is secured to the sides and back of the saddle and is not readily removable; the aft-cover-panel assembly (2) which encloses the back end of the enclosure; and the top panel assembly (3) which encloses the top part. The aft cover and top panels are fastened to the side panel by quick-action fasteners.

Dome Assembly

The dome assembly is made of magnesium alloy, specification No. AN-M-29. The assembly is the enclosure for the turret assembly and is secured to a flange on the inner ring by screws. Two access doors, one located on the elevation-drive and the other on the azimuth-drive side of the turret, permit servicing of the turret without removing the dome. These doors are quickly removed by quick-action fasteners. The rear part of the dome is removable to facilitate servicing of the guns.

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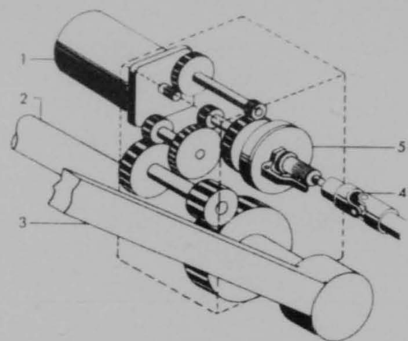

1. MOTOR
2. TORQUE TUBE
3. CRANK ARM
4. HAND CRANK
5. CLUTCH ASSEMBLY

Figure 2—47. Schematic Diagram of Retracting Gear Unit.

Retracting Mechanism

The retraction mechanism (Figure 2-47) is used to extend the turret into its firing position and to retract it inside the airplane's fuselage while flying to and from the combat zone. After the turret is retracted, a portion of the fairing slips over, covering and sealing the opening through which the turret projected. The only difference among these four assemblies is in the position of the retracting-gear unit with respect to the turret.

A crank arm is fastened on one end of the gear unit and a torque tube is fastened on the other end. On the opposite end of the torque tube, a second crank arm is fastened. The two crank arms are each connected to a pivot arm. The opposite ends of the pivot arms are pinned to the inboard side of the outer ring of the turret. The outboard side of the turret outer ring is hinged to the airplane. The gear housing and torque-tube bracket are mounted on the outboard side of the airplane. A connector bracket is fastened to one side of the gear housing from which an electric cable goes to the position switches on the crank arm nearest the gear housing.

Retracting Gear Unit

(Figure 2-47). The gear unit consists of ten gears (five sets). The first gear is on the electric motor shaft and has a ratio of 2426.66 to 1 of the crank arm. Between the fourth and fifth gears there is a clutch (5) which disengages the motor drive from the rest of the gear train when the hand crank (4) is pushed onto the shaft. In turn, the shaft forms a part of the fifth gear. The tenth gear is splined directly to the crank arm (35-tooth spline) (3) and the torque tube (34-tooth spline) (2).

Electric Drive Motor. The electric drive motor is a three-phase, 400 cycle, 208-volt motor, rated 10,200 rpm and 0.76 horsepower. The motor is equipped with a thermal-overload switch. Rotation of the motor is in either direction, depending upon the polarity of the

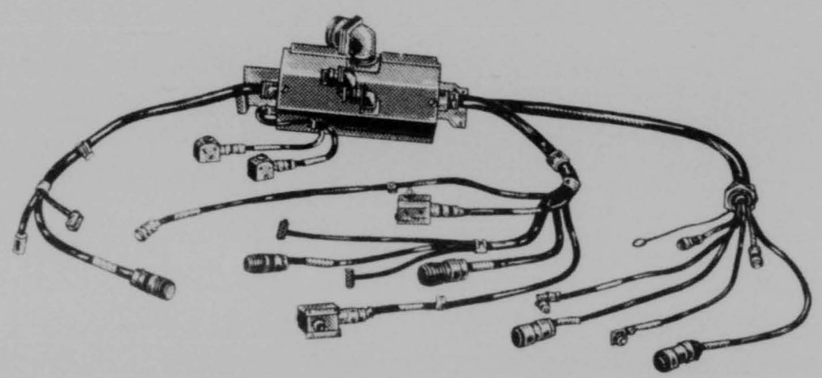

Figure 2—48. Turret Junction Box.

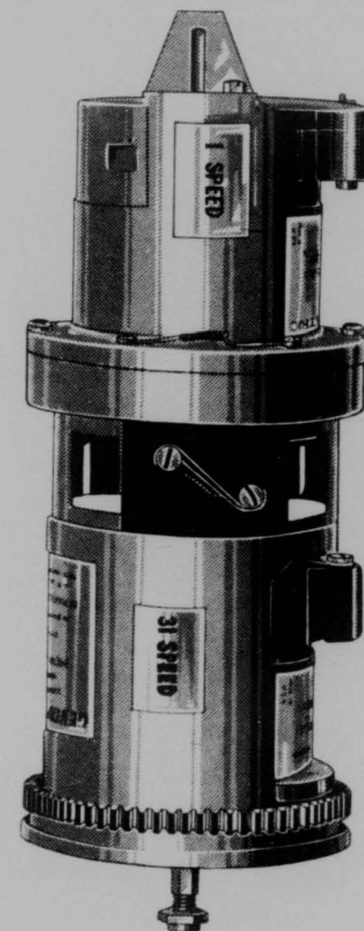

Figure 2—49. Selsyn Control Transformer.

control signal. A solenoid-operated brake prevents rotation of the motor armature and holds the turret in any position when the motor is not energized.

Torque Tube. The torque tube is made of seamless alloy steel and is supported through the 34-tooth spline by a needle bearing in the gear housing. The opposite end is supported by the bearing in the torque tube bracket. On this end, away from the gear housing, is a 35-tooth spline which supports the second crank arm. By means of the 34-tooth or 35-tooth spline on the torque tube, the second crank arm can be adjusted in 0.015-inch increments, as measured at the pin on the inboard side of the turret outer ring.

Crank Arms and Pivot Arms. The two pivot arms, controlled by the two crank arms, move the outer ring of the turret up to horizontal position for firing and down 67 degrees 15 minutes to the retracted position.

Retraction-mechanism Connector Bracket and Limit Switches. The connector bracket is a spot-welded sheet-metal assembly which supports the cable from the control box and the cable to the limit switches. The limit switches are so arranged on the crank arm that one switch cuts off the power to the drive motor when the turret reaches its firing position, and the other switch cuts off the power to the drive motor when the turret reaches its stowed position. An adjustable bracket on the upper arm actuates the plunger arm of this switch. The latter switch acts also as a holding circuit; it prevents the fairing cover from being closed over the turret opening until the turret is stowed and fully retracted.

Turret Junction Box

The turret junction box (Figure 2-48) is mounted on the inner ring. All electric power to the turret feeds into the junction box. Cables from the junction box take power to the firing solenoids, gun heater, drive motors, Selsyns, limit switches, and gun chargers. A relay, located in the junction box, controls the drive motors during the time the contour follower is in effect.

Selsyn Control Transformer Model 2JB15B1 (Tandem Unit)

The Selsyn control transformers (Figure 2-49) which are mounted on the turret-drive assemblies correspond to the Selsyn generators on the sighting station. One-speed and 31-speed Selsyn control transformers are provided for both the azimuth and the elevation Selsyn systems. For convenience the turret

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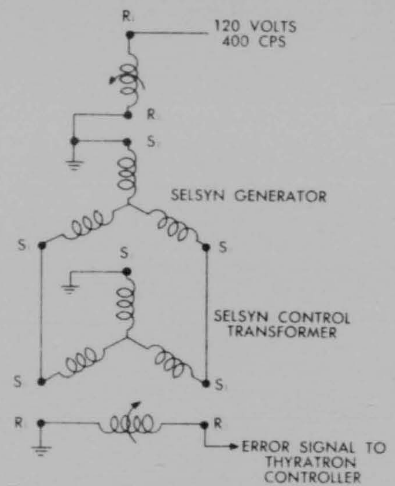


Figure 2—50. Selsyn Generator and Control Transformer Connection Diagram.

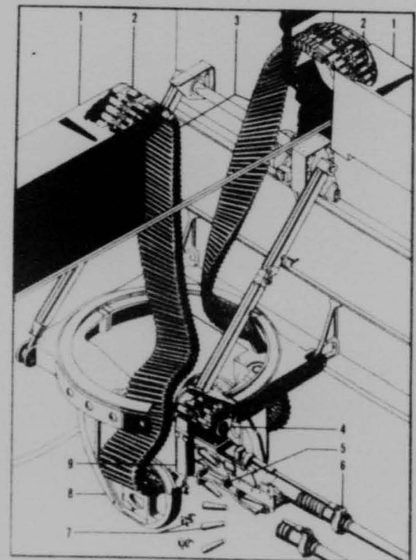
Selsyns are mounted in tandem. The 1-speed Selsyn control transformer is mechanically connected by gearing to the 31-speed Selsyn which, in turn, is geared to the turret.

A single Selsyn control transformer is a small electric device which consists of the following basic elements: a stator, a rotor, an end shield, and a connector. Actually, the electrical characteristics of the Selsyn control transformer differ considerably from those of the Selsyn generator so that these elements are not interchangeable in the system. One of the apparent differences is in the shape of the rotor. The Selsyn control transformer has laminated, round rotor punchings while the Selsyn generator has dumbbell-shaped punchings. It has a higher impedance than the Selsyn generator. The voltage on the rotor of the Selsyn control transformer is rated 120 while on the rotor of the Selsyn generator the maximum voltage is rated 57.5. Electric connections to the Selsyn control transformer are made through connector contacts identified by "R_1", "R_2", "S_1", "S_2", and "S_3".

The three stator windings of the control transformer are electrically connected through system wiring to the stator windings in the Selsyn generator so that the voltages appearing in the windings of the Selsyn generator are reproduced in magnitude and polarity in the stator windings of the Selsyn control transformer. (Figure 2-50). The resulting magneto flux in the control-transformer stator induces a voltage in the rotor by transformer action which is the signal voltage fed to the thyratron controller.

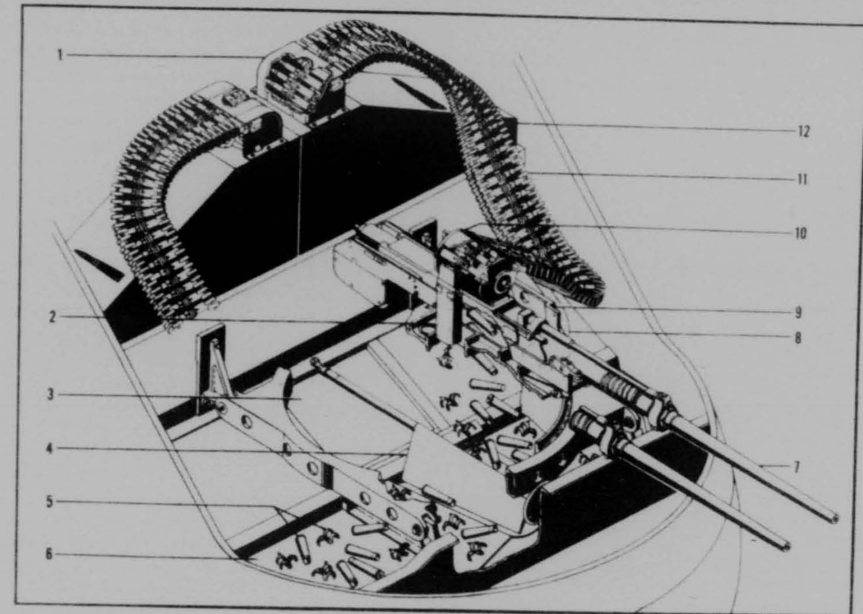
Non-interchangeable Items of Upper Turrets

The upper forward turrets are identical with the upper aft turrets except for the fire interrupter cams, azimuth stops, and case-and-link chute assembly. The fire interrupters have different cam patterns for each turret (refer to table II). Contour-follower assemblies are interchangeable but the contour patterns must be adjusted for each turret (refer to above paragraph).



1. AMMUNITION BOX
2. AMMUNITION BOOSTER
3. AMMUNITION FEED CHUTE
4. FEED MECHANISM
5. SADDLE
6. GUN
7. EJECTED LINKS AND CASES
8. SADDLE SUPPORT
9. LINK EJECTION CHUTE

Figure 2—51. Route of Incoming Ammunition and Ejected Cases and Links—Lower Turret.



1. AMMUNITION BOOSTER
2. LINK EJECTION CHUTE
3. ACCESS DOOR FOR REMOVAL OF LINKS AND CASES
4. AMMUNITION WIPER
5. LINKS AND CASES
6. AMMUNITION TROUGH
7. GUN
8. SADDLE SUPPORT
9. SADDLE
10. FEED MECHANISM
11. AMMUNITION FEED CHUTE
12. AMMUNITION BOX

Figure 2—52. Route of Incoming Ammunition and Ejected Cases and Links—Nose Turret.

Description of Lower Turret. The two lower turrets are essentially the same as the upper turrets, except for minor modifications which were necessary to adapt the turrets for operation in an inverted position.

Differences Between Lower Turrets and Upper Turrets. The lower turrets are identical to the upper turrets with the following exceptions: The sealing of the dome assembly to the gun enclosure; the lower dome access panels have blisters to allow greater clearance for the ammunition feed chutes; the ejected cases and links pass through the bottom of the gun enclosure; the feed chutes pass through, rather than over, the inner ring and saddle supports and saddle assembly (Figure 2-51); the lower-turret gun chargers are designed for installation on the lower side of the guns. The ammunition boosters are similar to those on the upper turrets except for the assembly of the housing and the gear unit. Also, one of the boosters has a horizontal inlet and outlet. The only difference between the upper and the lower contour followers is in the contour pattern. In the retraction mechanism the gear housings are mounted forward of the turret. The lower-turret interrupters differ from the upper-turret interrupters in their cam patterns and in the position in which the interrupter is mounted on the inner ring.

Gun Enclosure Assembly. The lower-turret enclosure is identical to the upper-turret enclosure except that it has four removable panels besides the side-plate assembly. The side-plate assembly is fastened to the sides of the saddle and is not readily removable. To the side plates are fastened the lower panel assembly, top panel assembly, front panel assembly, and rear panel assembly. These four panels are fastened to each other and to the side plates by quick-action fasteners, which facilitate the servicing of the guns, the gun chargers, and the feed mechanism.

Detailed Description of Nose Turret

The nose turret is essentially the same as the upper turrets, except that is has no contour follower, fire interrupter, or retraction mechanism.

Differences Between Nose Turret and Upper Turrets. The gun enclosure is similar to that of the upper turrets except that it is sealed to the turret enclosure, which, is sealed to the airplane fairing. The inner and outer ring assembly is designed differently to accommodate the azimuth stops and limit switches. These stops and switches are mounted on the top of the ring assembly. The junction box is mounted vertically between the two guns. The gun chargers are designed for installation on the lower side of the gun to avoid interference with the airplane structure. The ejected links and cases fall through the bottom of the saddle into a trough located in the airplane fuselage. (Figure 2-52).

Dome Assembly. The dome assembly (turret enclosure) made of magnesium alloy, specification No. AN-M-29, is secured to the inner-ring flange by screws and is pivoted at the top through a centering plate and support assembly which is fastened to the airplane fuselage. There are five access doors in the nose dome. Two access doors, one located on the elevation and the other on the azimuth side of the turret, permit a limited amount of servicing of the turret. The two lower access doors, when removed, permit the installation of the nose turret on the airplane with the dome mounted. The front access door, when removed, makes it possible to mount the dome on the turret after the turret is installed in the airplane.

SECTION III—PEDESTAL SIGHTING STATION

1. INTRODUCTION

This section contains instructions on the Models 2CSR4B5 and 2CSR4B6 pedestal sighting stations used with the remote-control turret systems for the B-36 airplane. The system is designed and manufactured by General Electric Company. (See Figure 2-53.)

2. DESCRIPTION

General

The term "sighting station" refers to the complete unit which mounts the retiflector sight, together with the controls used by a gunner in tracking and ranging a target. (Figure 2-53). A sighting station also includes the equipment which indicates to the computer the direction, angular velocity, and range of the target. The lower-right aft and the lower-left aft sighting stations are of the pedestal type. Fixed transparent enclosures protect the gunners from the slipstream of the airplane while they scan the maximum sky area from their individual stations.

Lower-right Aft Sighting Station

This blister is equipped with a pedestal sighting station. In operating this station, the gunner grasps both handwheels and moves the sight manually in elevation and azimuth. To enlarge the gunner's field of vision, the sighting station is bolted to a plate which is attached to the airplane structure so that the sight protrudes well into the transparent blister. Elevation travel is limited to 60 degrees above and 90 degrees below horizontal. Azimuth movement is 210 degrees. Because the pedestal-type sighting station is the same for both the left and right blisters, this description will cover both. The approximate overall height of the sighting station is twenty inches and the approximate weight thirty-six pounds.

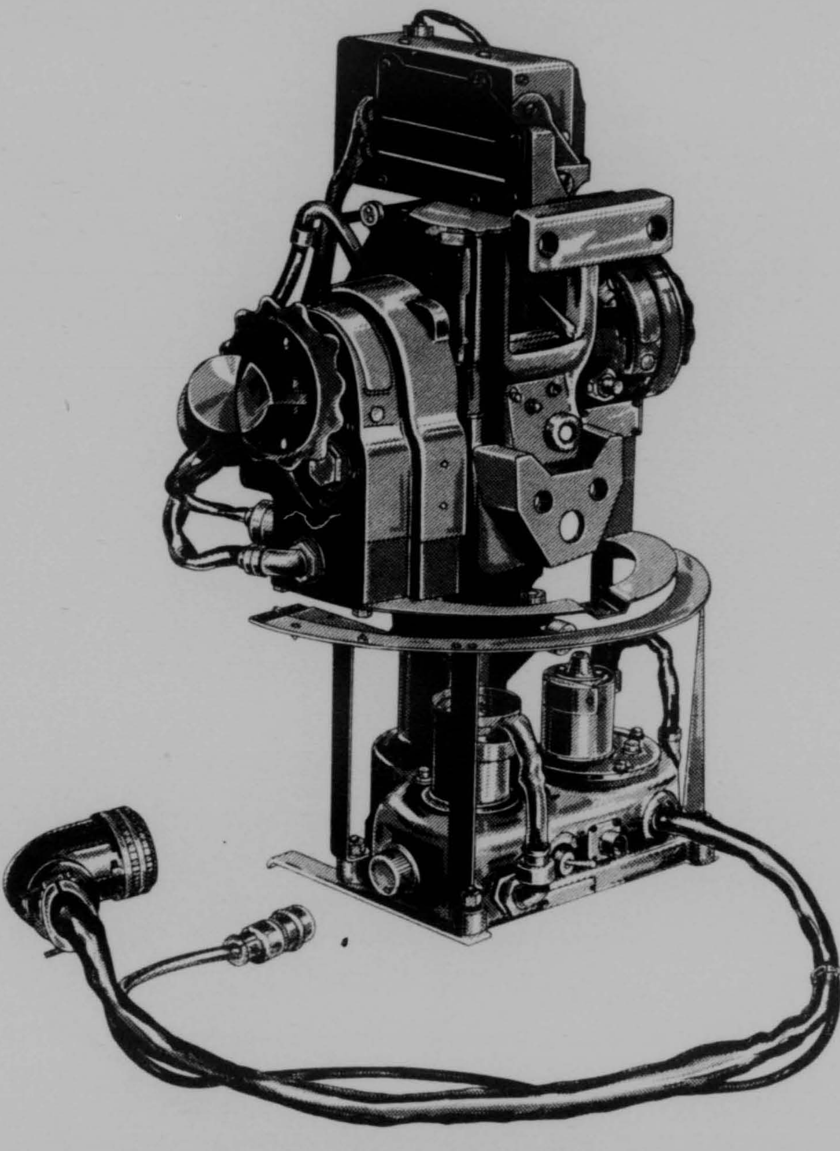
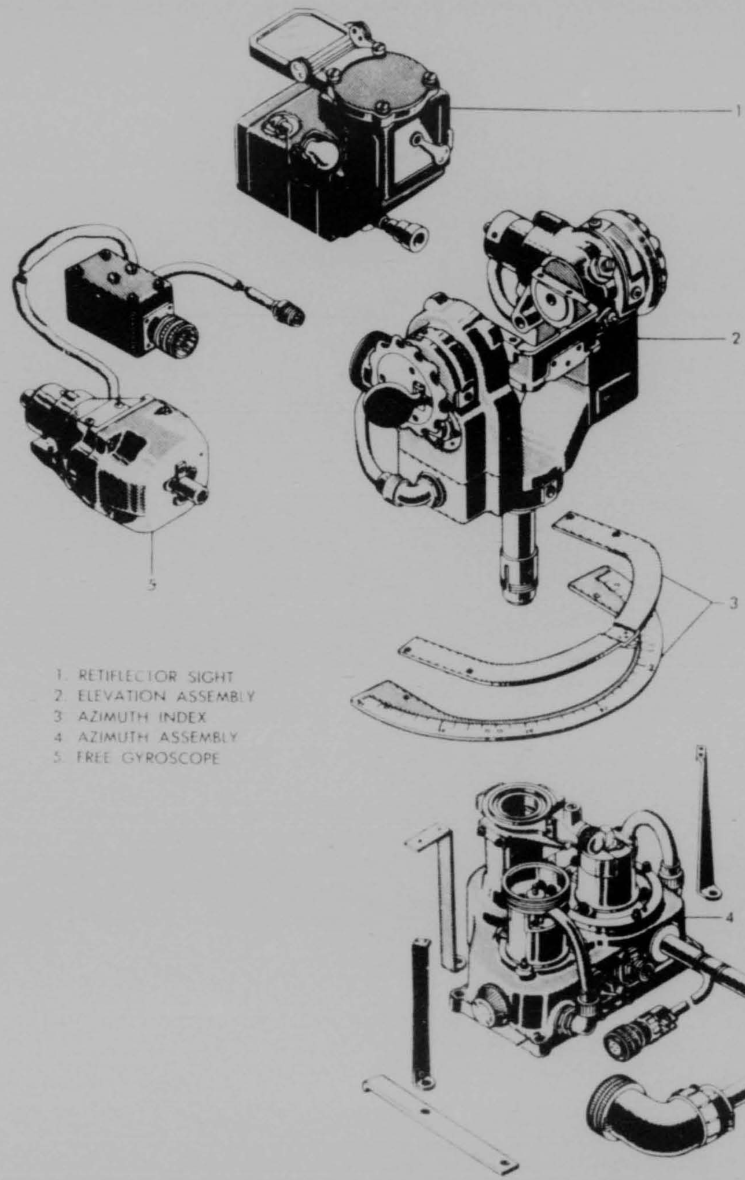
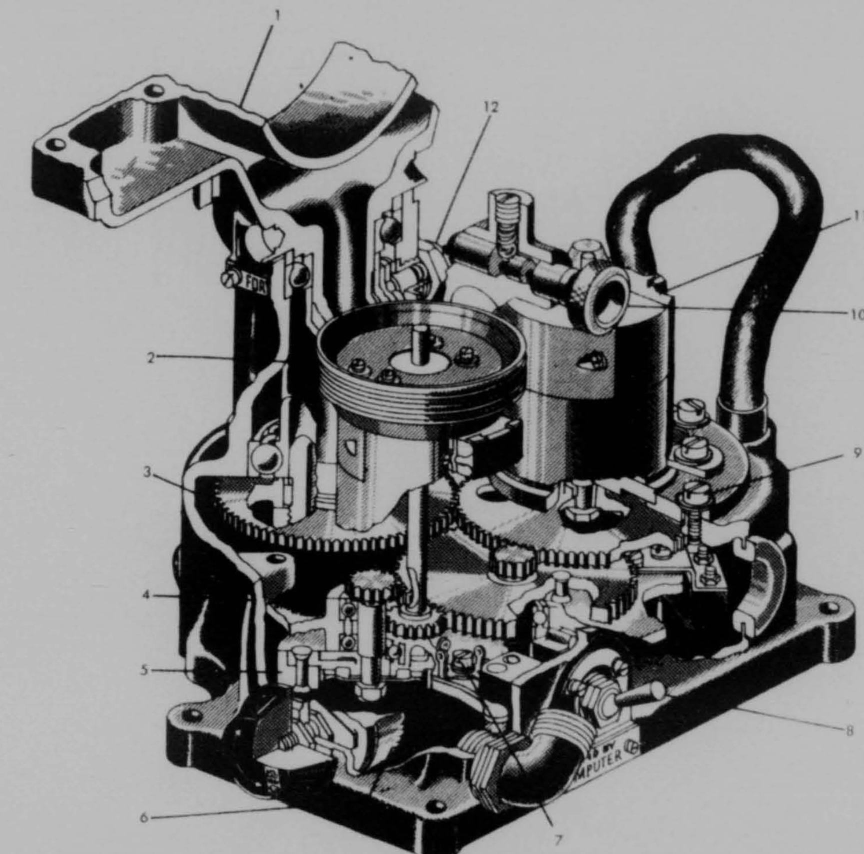


Figure 2—53. Overall View of Pedestal Sighting Station, Models 2CSR4B5 and 2CSR4B6.



1. RETIFLECTOR SIGHT
2. ELEVATION ASSEMBLY
3. AZIMUTH INDEX
4. AZIMUTH ASSEMBLY
5. FREE GYROSCOPE

Figure 2–54. Exploded View of Pedestal Sight.



1. ELEVATION SUPPORT
2. 31-SPEED SELSYN GENERATOR
3. AZIMUTH GEAR DRIVE
4. GEAR HOUSING
5. INERTIA WHEEL
6. RETICLE RHEOSTAT
7. GROUNDING LUGS
8. COMPUTER STAND BY SWITCH
9. SCREW
10. AZIMUTH STOW PIN
11. ONE SPEED SELSYN GENERATOR
12. AZIMUTH FRICTION SCREW

Figure 2–55. Cutaway View of Azimuth Assembly.

The major assemblies (Figure 2-54) are the azimuth assembly (4), the elevation assembly (2), the retiflector sight (1), and the gyroscope (5) and camera.

3. AZIMUTH UNIT ASSEMBLY

The azimuth assembly (Figure 2-55) forms the base for the pedestal sighting station. It transmits signal voltages, which indicate the exact position of the line in azimuth, through the computer to the azimuth Selsyn-control transformers on the turret. The basic assemblies are the Selsyn-generators—a 1-speed unit (11) and a 31-speed unit (2)—an azimuth gear train, the inertia wheel (5), and a cast

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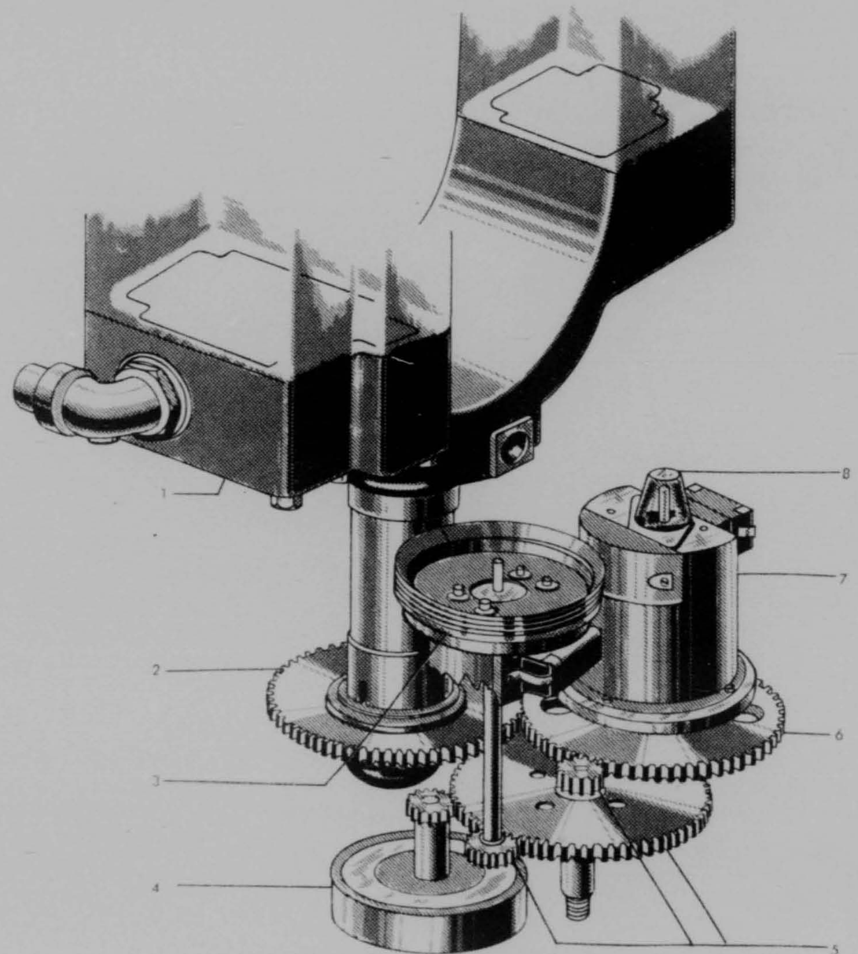


1 YOKE
2 INPUT SPUR GEAR
3 31-SPEED SELSYN GENERATOR
4 INERTIA WHEEL
5 GEARING TO 31-SPEED SELSYN
6 GEARING TO ONE-SPEED SELSYN
7 ONE-SPEED SELSYN GENERATOR
8 CAP

Figure 2–56. Cutaway View Showing Azimuth Selsyn Gearing.

aluminum-alloy gear housing (4). Also located on the gear housing are the computer stand by switch (8), the azimuth stow pin (10), the azimuth limit stops, the reticle adjustment rheostat (6), and the azimuth friction screw (12).

Selsyn-generator Units. The Selsyn units (2 and 11) (Figure 2-55) are mounted on the gear housing (4). So far as mechanical construction and electrical operation are concerned, these Selsyn units are identical to those used on the yoke sighting station. The 31-speed Selsyn unit is mounted in the following manner: its flanged end-shield, on the shaft end, has an adapter attached to it which permits the Selsyn to fit snugly into a rabbeted recess in the top of the gear housing. Three clamps hold it securely in place. The clamps, which fit over the edge of the Selsyn's flanged end-shield, are held by three screws and lock washers which fit into tapped holes in the gear housing. An adapter is attached to the top of the 31-speed Selsyn which permits connection with the lead checker. The 1-speed Selsyn is attached to a mounting plate in the same manner. A cover is placed over the 1-speed Selsyn for protection. Four screws hold the mounting plate in place on top of the gear housing.

Gear Train. (Figure 2-56). An input spur gear (2) on the end of the yoke shaft meshes with an identical spur gear (6) attached to the rotor of the 1-speed Selsyn generator (7). As the yoke is rotated in azimuth, the rotor of the 1-speed Selsyn unit makes one full revolution for every full revolution of the yoke. The spur gear (6), on the rotor shaft on the 1-speed Selsyn, drives the gear train (5) for the 31-speed Selsyn generator (3). The gear ratio of the train is such that the rotor of the 31-speed Selsyn-generator would (if the limit stop in the sighting station permitted) make 31 complete revolutions for each 360-degree rotation of the yoke.

Inertia Wheel Assembly. The inertia wheel (4) (Figure 2-56) is driven by a pinion meshing with the intermediate gear on the gear train. The flywheel action of the wheel tends to smooth out the movement of the sighting station as it is moved in azimuth.

Gear Housing. The housing consists of an aluminum-alloy casting containing two ball bearings which support the elevation assembly. (Figure 2-55). The azimuth gear train, inside the housing, transmits the azimuth motion of the elevation yoke to the 1- and 31-speed Selsyns (2 and 11).

Computer Standby Switch

This luminous toggle-switch (8), (Figure 2-55) is mounted on the front of the azimuth Selsyn-gear housing. The switch allows the Selsyn signal from the sight to by-pass the computer and go directly to the Selsyn control-transformers on the turret. This switch can be used to make the system noncomputing, if the computer is damaged by gunfire.

Azimuth Friction Screw. This device (12), (Figure 2-55) which is utilized by the gunner in adjusting the sighting station for freedom of movement in azimuth, is located on the side of the azimuth housing. Tightening or loosening the screw increases or decreases the pressure on the rotating drive shaft.

Azimuth Stow-pin. The stow-pin (10), (Figure 2-55), used to stow the sighting station in any one of three positions in azimuth, is located between the two Selsyn units on the front of the bearing support for the yoke. A ball, spring, and limit-screw assembly hold the pin in its "out" or "in" position.

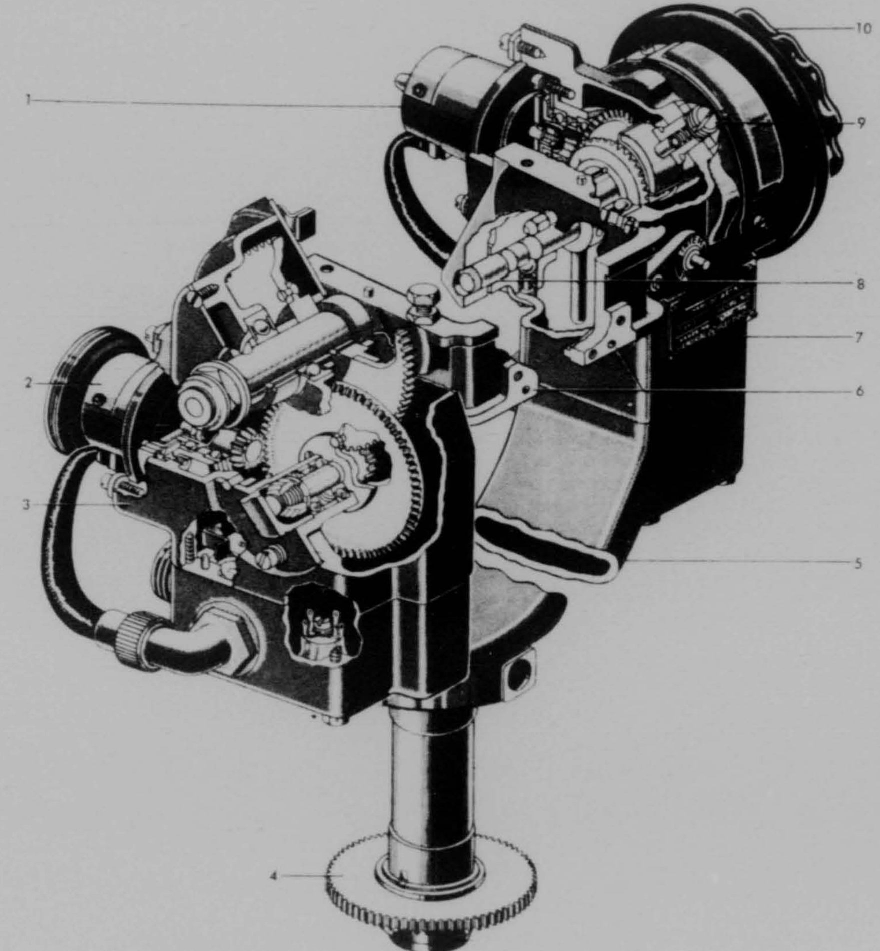
Azimuth Limit Stops. These stops, which limit rotation of the sighting station in azimuth, are located near the stow-pin assembly. Two metal clamps, one for either side of the stow-pin assembly, carry rubber snubbers which engage ears on the yoke and stop rotation of the sight when it has reached the limits of travel in azimuth.

Reticle Adjustment Rheostat

A black composition knob (6), (Figure 2-55), extending from the left-hand side of the gear housing, is used to turn the rheostat to increase or decrease the brightness of the reticle image.

Electrical Connections

(Figure 2-54). Electrical connections for incoming power and outgoing signals are



1. ONE-SPEED SELSYN GENERATOR
2. 31-SPEED SELSYN GENERATOR
3. LEFT-HAND GEAR BOX
4. AZIMUTH GEAR DRIVE
5. HOLLOW YOKE
6. SIGHT YOKE
7. RIGHT-HAND GEAR BOX
8. ELEVATION STOW PIN
9. ELEVATION FRICTION SCREW
10. RANGE INPUT HANDWHEEL

Figure 2–57. Cutaway View of Elevation Assembly.

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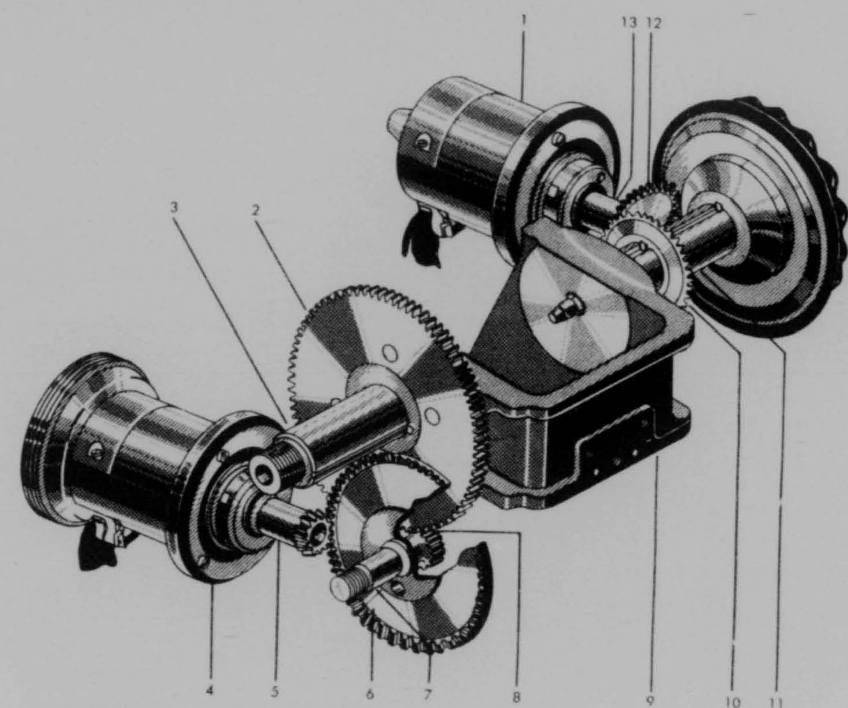

1. ONE-SPEED SELSYN GENERATOR
2. SPUR GEAR
3. YOKE SHAFT
4. 31-SPEED SELSYN GENERATOR
5. BEVEL GEAR
6. BEVEL GEAR
7. SHAFT-AND-GEAR ASSEMBLY
8. PINION GEAR
9. SIGHT YOKE
10. BEVEL GEAR
11. HOLLOW YOKE SHAFT
12. BEVEL GEAR
13. SHAFT

Figure 2–58. Cutaway View Showing 1- and 31-Speed Elevation Selsyn Gear Driving.

made through a cable and connector at the base of the azimuth assembly. Power is brought into the rotor and taken off the stator of each Selsyn-generator through a cable extending from the sides of the azimuth housing to each Selsyn.

4. ELEVATION UNIT ASSEMBLY

(Figure 2-57). The function of this assembly is to mount the retiflector sight and to permit movement of the sight in elevation. The elevation Selsyn-generators (1 and 2) transmit signal voltages from the sighting station through the computer to the elevation control-transformers on the turret(s). These signal voltages indicate the exact position of the line of sight in elevation. The major parts of the elevation Selsyn-generator assembly are: two Selsyn generators (a 1-speed unit and a 31-speed unit); two handwheels, by means of which the gunner moves the sight in elevation; two gear trains for connecting the rotors of the Selsyns with the handwheels; an elevation support yoke (5) which carries the entire elevation Selsyn-generator assembly; a sight yoke (6) for supporting the retiflector sight and a range handle (10); an elevation friction screw (9); and lock (8).

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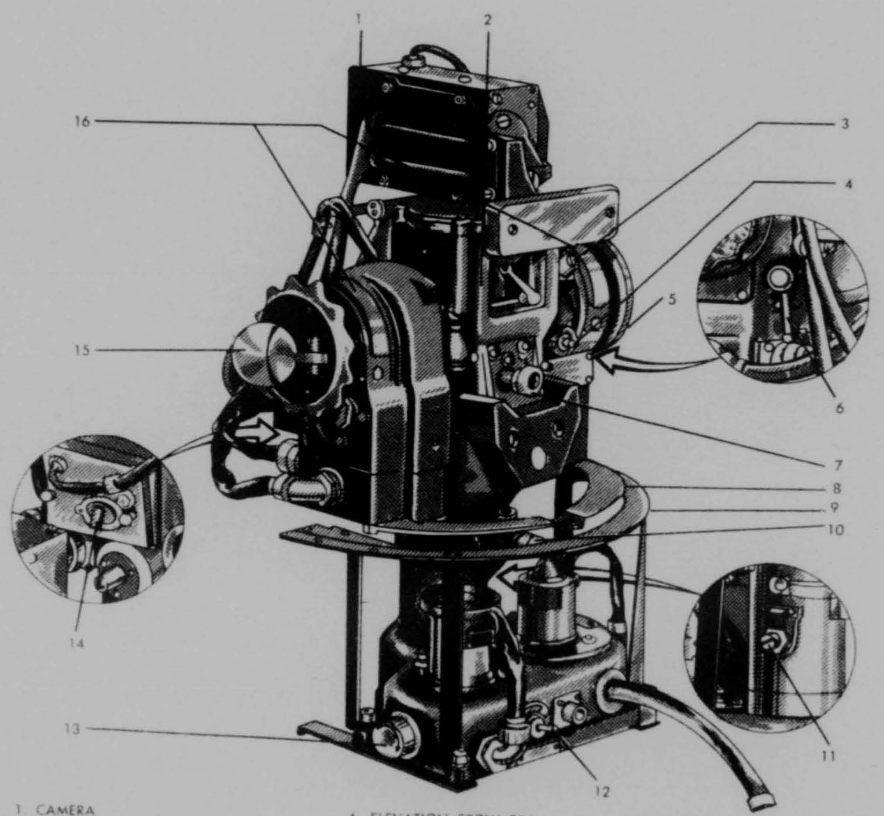

1. CAMERA
2. FRONT SUPPORT-RETIFLECTOR SIGHT
3. ELEVATION FRICTION SCREW
4. INTERPHONE SWITCH
5. RANGE INPUT HANDWHEEL
6. ELEVATION STOW PIN
7. RANGE INPUT KNOB
8. INDICATOR
9. AZIMUTH SCALE
10. AZIMUTH LOCK
11. AZIMUTH FRICTION SCREW
12. COMPUTER STAND BY SWITCH
13. RETICLE RHEOSTAT
14. RETICLE LAMP SWITCH
15. ACTION SWITCH
16. FIRING TRIGGERS

Figure 2–59. Location of Switches and Adjustments on Pedestal Sight.

Selsyn-generator Units

The elevation Selsyn-generators are identical in construction to those used on the yoke sighting station. The 31-speed Selsyn (2), (Figure 2-57) is mounted on the rear of the left-hand gear box (3). The shaft end of the 31-speed Selsyn has an adapter attached to it which permits the Selsyn to fit into a rabbeted recess in the gear-box housing (3). It is held in place by three clamps. The 1-speed Selsyn is attached to the right-hand gear box (7) in the same manner.

31-speed Selsyn Gear Train

(Figure 2-58). This assembly is housed in the left-hand gear box and connects the left handwheel with the rotor of the 31-speed Selsyn generator (4). The left handwheel is mounted on the end of a hollow sight-yoke shaft (3) which is supported at either end by ball-bearing assemblies which, in turn, fit into opposite sides of the gear box. As the gunner turns the left handwheel, the sight yoke (9) is raised or lowered. Inside the gear box a large spur gear (2), attached to the hollow drive shaft of the yoke (3), engages a pinion (8) on an intermediate shaft-and-gear assembly (7). Also mounted on this intermediate shaft is a large bevel gear (6) which meshes with a small bevel gear (5) on a short shaft which drives the rotor of the 31-speed Selsyn. As the gunner elevates or depresses the sight, the gear train turns the rotor of the 31-speed Selsyn. The gear ratio of this train is such that the rotor of the 31-speed Selsyn-generator would, if the limit stops of the sighting station permitted, make 31 complete revolutions for each single revolution of the handwheel. Ball-bearing assemblies provide freedom of rotation for the gear shafts.

1-speed Selsyn Gear Train

(Figure 2-58). As in the case of the left handwheel, the right handwheel is also mounted on a hollow shaft (11) supported by a ball-bearing assembly which fits into a recess in the side wall of the right-hand gear box. The shaft extends through the side wall of the gear housing and is part of the sight yoke (9). The gunner can rotate this handwheel and elevate or depress the retiflector sight. Inside the gear box ,the hollow shaft (11) mounts a bevel gear (10) which meshes with an identical bevel (12) mounted on one end of a shaft (13) whose other end carries a simple coupling. The coupling connects with a rotor of the 1-speed Selsyn. Because both bevel gears are identical, one complete revolution of the handwheel will cause one complete revolution of the rotor of the 1-speed Selsyn.

Elevation Support Yoke

(Figure 2-57). This yoke (5) is hollow and Y-shaped. The base of the "Y," which is also a hollow shaft, fits into the extended bearing support on the azimuth assembly. The spur gear (4), keyed to its lower end, engages the gear train of the azimuth Selsyn-generator assembly so that when the yoke is rotated, the azimuth gear train is set in motion. On the left-hand side of the front of the yoke is a leveling pad for use in mounting a level during harmonizing.

Action Switch

(Figure 2-59). This disc-like switch (15) is mounted on the left handwheel. It is held in a normally-open position by a spring assembly. When the gunner closes it, by pressing it with the palm of his hand, the turret guns will swing into alignment with the line of sight providing that the control-box switches are properly positioned and the computer switched to "out." Wiring for the action switch is brought into the elevation assembly through a hollow yoke and reaches the action switch through the hollow drive shaft carrying the left handwheel. A slot in this drive shaft permits the entry of the wiring and prevents undue twisting of the wiring when the sight is rotated through 150 degrees in elevation.

Right Handle

This handle (5) (Figure 2-59) is similar in contour to the left handwheel. It is mounted on the right handwheel. The range handle is mounted on a grooved shaft which extends through the hollow sight-yoke shaft and connects with the gear train of the retiflector

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sight. It is held in place by a spring-actuated pin that engages a groove in the shaft.

Sight Yoke

(Figure 2-60). A U-shaped yoke with supporting shaft is used to mount the sight. This yoke pivots between the arms of the main yoke and is supported by the two drive shafts from the right and left handwheels. Two pins on the sight mounting surface assure proper alignment of the retiflector sight. The front of the yoke is drilled and tapped to support a front bracket which supports one end of the gyroscope unit. The mounting surface for the front bracket has two pins to assure proper alignment of the bracket and hence the gyroscope.

Elevation Friction Screw

This is a device which provides for adjustment of the drag desired in the movement of the sighting station in elevation. The friction screw (3) (Figure 2-59) is located on the front of the right-hand gear box. Tightening or loosening of the screw increases or decreases pressure on a metal shoe which has a felt liner that rides on the drive shaft of the sight yoke. A lock nut holds the screw in position after the friction adjustment is made.

Elevation Stow-pin

(Figure 2-59). The elevation stow-pin (6) is used to lock the elevation assembly when stowing the sight station. It is located at the rear of the right-hand gear box and consists of a pin mounted in a flange on the gear box. It slides into a hole on the rear of the sight yoke to lock the sight yoke in the horizontal position.

Note: The proper spring tension is set at the factory and should not be changed.

Firing Triggers

(Figure 2-59). The two nonfiring triggers (16) are mounted on the front of the right- and left-hand gear boxes in a convenient position for the gunner to press them with his thumbs. Pressure on either trigger will actuate a relay which closes the firing circuit to

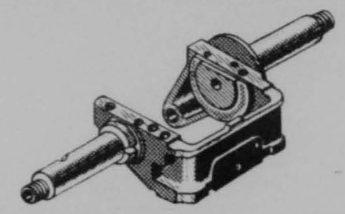


Figure 2—60. Sight Yoke.

the guns and, if the switch on the control box is in the "combat" position, the guns will immediately begin to fire.

Elevation Lock

The elevation lock (1) is located between the right elevation handwheel and the main yoke. Screws on the yoke lock are tightened to hold the sight in elevation during harmonizing.

Limit Stops

Mounted on the cover of the 31-speed gear housing are the stops which limit the travel of the sight in elevation.

Electrical Connections

The wiring for the Selsyns, retiflector sight, gyroscope, camera, and firing trigger is brought from the azimuth assembly into the elevation assembly through the hollow shaft and hollow arms of the elevation-support yoke.

Azimuth Scale

(Figure 2-59). The azimuth scale (9), located between the azimuth and elevation units, together with the indicator (8), indicates degrees of travel of the line of sight in a horizontal plane (azimuth). It is used for harmonization of the system, for checking computer operation and as a navigation drift scale. The scale is a semicircular piece, graduated clockwise from 0 degrees to 180 degrees in steps of 5 degrees and marked every 30 degrees. It is attached to two supports, one left and one right, which are bolted to the base of the azimuth unit and position the scale at a point level with the bottom of the great boxes on the elevation unit.

Indicator

(Figure 2-59). The indicator (8) is an index which, together with the azimuth scale, shows the degrees in azimuth of the line of sight. It is located to the bottom of the left and right gear boxes of the elevation unit. A pointer, located on the center of the indicator, overlaps onto the azimuth scale to indicate the degrees in azimuth.

Gyroscope

(Figure 2-61). The right blister sighting station has one free-gyroscope (9). It is mounted on the sighting station to furnish the computer with data onsight movement, both in elevation and azimuth, so the computer can calculate the correct predictions. For further information on computers, see AN 11-70AA-54. For information on the free-gyroscope, see AN 11-70AA-52.

Retiflector Sight

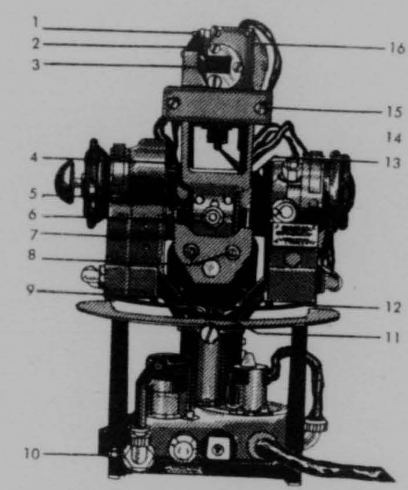
The retiflector sight (1) (Figure 2-54) is mounted on the sight yoke. It has a DC range output. The sight on the pedestal sighting station has the assembly containing the retiflector plate and the sky filters attached to the unit so that the line of sight is parallel to the long axis of the sight body. For further information refer to AN 11-70AA-42.

Camera (Gun Type, AN-N6)

This camera assembly (1), (Figure 2-59) with the exception of the camera adapter lens, is Government - furnished equipment U. S. Army Specification No. 75-366. It is mounted above the retiflector sight, and is used to make a permanent record of combat action.

Components

The camera is the 16mm type with a magazine containing fifty feet of film. The standard speed is sixteen frames per second although speeds of thirty-two and sixty-four frames per second are obtainable by setting the camera speed knob. Pictures are taken through the sight reflecting glass by means of a special periscope-type camera-adapter lens.



1. NUT
2. MOUNTING BRACKET
3. ADAPTER
4. GYRO SUPPORT
5. FILLISTER-HEAD SCREW
6. TARGET INPUT KNOB
7. COUNTERWEIGHT
8. FILLISTER HEAD SCREW
9. FREE GYROSCOPE
10. MOUNTING LUG
11. INDICATOR AND POINTER
12. SCREW
13. SCREW
14. RETIFLECTOR SIGHT
15. PAD
16. CAMERA

Figure 2—61. Gunner's Side of Pedestal Sight.

Operation

When the gunner presses his firing trigger the camera action starts. The camera records the target, reticle image, target size, and the range distance. An overrun control continues the picture-taking action, for a limited period, after the gunner has released the firing trigger.

Camera Adapters

(Figure 2-61). The sighting stations use camera adapters which enable cameras located adjacent to the retiflector sight to photograph the target as it appears on the sight reflector plate. The adapters, which are miniature periscopes, mount on the camera. On the yoke sighting station, the adapter extends

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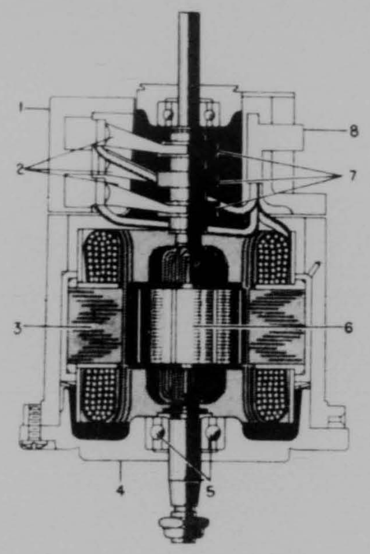


1 Collector end shield
2 Brushes
3 Stator
4 End shield
5 Ball bearings
6 Rotor
7 Collector rings
8 Connector

Figure 2–62. Sectional View of Selsyn-Generator Model 2J15A1.

from the camera in a vertical plane to the retiflector sight. The adapter has an adjustable light opening which must be set for speeds and light conditions.

Detailed Description of Lower-left Aft Sighting Station

The lower-left aft sighting station is identical to the lower-right aft sighting station with the exception of the zero positioning of the azimuth with respect to the sighting station, the position of the nameplate on the main yoke which indicates the "forward" position, and the azimuth scale which is marked clockwise from 180 degrees to 360 degrees.

Detailed Description of Selsyns

A Selsyn is a small, self-synchronous instrument used as an electrical means of transmitting data concerning the relative angular positions between two or more remotely located devices. In the remote-control turret system, Selsyns are used to transmit the angular position of the sight and guns.

Selsyn Generator Model 2J15A1

The Selsyn generator is, mechanically, a miniature bipolar, rotating-field, three-phase alternator. The rotor is wound with a single-phase concentrated winding, and the stator with a three-phase, distributed "Y" connected winding.

Electrically the Selsyn acts as a transformer, and voltages and currents are single phase. The rotor is excited by an alternating voltage source, one phase of the aircraft's three-phase, 400-cycle power supply. By transformer action, voltages are induced into the three stator windings, the magnitude of the voltage in each depending upon the angular position of the rotor.

Mechanically the Selsyn generator consists of a stator carrying a three-coil winding, a rotor carrying a single winding which revolves inside the stator, an end shield forming part of the housing for the elements, and a connector for making electrical connections with the Selsyn.

The stator (3) (Figure 2-62) consists of three windings assembled within a slotted, laminated core which is fitted into the end shield (4). A lead from one end of each of the three windings extends to contacts (identified as "S_1", "S_2", and "S_3"), carried by the connector (8). The other ends of the three stator windings are connected internally in the Selsyn.

The rotor (6) of the Selsyn generator consists of a single coil wound on a laminated iron core. Opposite ends of the rotor are supported in ball bearings (5) carried by the two end shields. The ends of the rotor winding are brought out to spaced collector rings (7) mounted on the rotor shaft. Brushes (2), electrically connected to contacts on the connector, ride on the collector rings providing an electrical connection to the rotor. The contact pins connected to the brushes are identified as "R_1" and "R_2". (Figure 2-63.)

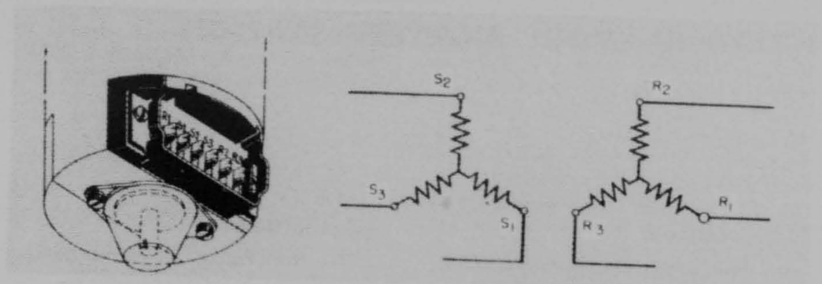


Figure 2–63. Connection Wiring Diagram for Selsyn-Generator, Model 2J15A1.

The rotor of the Selsyn generator is energized by 400-cycle alternating current from one phase of the aircraft's three-phase supply source. This produces a magnetic flux in the rotor winding which, in turn, and by transformer action, produces a voltage in each of the three windings of the stator. The rotor is geared to the sighting station so that as the sight is moved manually, the rotor is turned, varying the voltage induced into the stator coils.

5. OPERATION

Principles of Operation

General. A "sighting station," as the term is used in this handbook, refers to the actual sighting equipment, that is, the sight and accessory equipment used by a gunner in tracking a target and in operating remotely located gun turrets. Specifically, a sighting station comprises; a sight, a means of moving the sight in azimuth and elevation, a direction in which the sight is pointing, and a means of transmitting to the computing system variations in range and lead.

Pedestal Sighting Station

The pedestal sight is of the retiflector type and the gunner moves it manually in both azimuth and elevation. The Selsyn follow-up system provides the means of indicating the position of the sight to the turret. In operating the sight, the gunner grips both handwheels and moves the sight manually in elevation and in azimuth. To enlarge the gunner's field of vision, the sighting station is bolted to a plate which is, in turn, so attached to the airplane's structure that it allows the sighting station to protrude well out into the stationary, transparent blister.

The Selsyn System

The azimuth and elevation Selsyn generators located on the pedestal sighting station send a signal corresponding to the sight position to the Selsyn control transformers located on the turret. Located electrically between the Selsyn generators on the sighting station and the Selsyn control transformers on the turret are the computer differential Selsyns. When no computer correction is necessary, the position signal from the sight is transmitted unchanged electrically to the control transformer. Corrections result in the sight position signal that is being modified, by the addition of the required correction angle. This new position signal is then sent on to the control transformers and the guns then point in the direction indicated by the sightin station, plus or minus the correction angle determined by the computer.

SECTION IV—YOKE SIGHTING STATION

1. INTRODUCTION

This section covers the description and operation of the yoke sighting station, models 2CSR4D1 and 2CSR4D2, designed and manufactured by the General Electric Company for the B-36 Remote Control Turret System.

2. DESCRIPTION

Upper (Yoke) Sighting Station

The four upper gunners' positions are equipped with yoke-type (Figure 2-64) sighting stations models 2CSR4D1 and 2CSR4D2. The difference between the two models lies in the position of the switch cam on the yoke spur gear. The D2 models are mounted upper-left forward and aft. As a consequence, the switch cams are mounted on opposite sides of the yoke spur gear. These sighting stations consist of an azimuth unit on which the "Y" yoke (8) is mounted vertically so that it rotates freely in azimuth. The arm ends of the sight yoke (1), on which the gyroscope (4), camera (3), and retiflector sight (2) are mounted, are supported by bearings in the elevation unit on the arm ends of the "Y" yoke (8). This permits the sight yoke to rotate in elevation about a horizontal axis. The sighting station may be rotated in azimuth and elevation by hand grips attached to the "Y" yoke and connected by a link to the sight yoke. The action switch (Figure 2-64), trigger (Figure 2-65), interphone button (Figure 2-64), and range grip (12) are mounted on these handles. The sighting station may be rotated in elevation through an arc from 90 degrees above horizontal to 40 degrees below horizontal, and in azimuth from $117\frac{1}{2} \pm 5$ degrees forward to 101 ± 0 degrees aft of the broadside position.

Azimuth Unit

This unit (Figure 2-65) forms the base for the sighting station and transmits signal voltages to indicate the azimuth position of the sight. Its basic assemblies are the cast alloy gear housing (16), the azimuth gear train (Figure 2-66), the two Selsyn generators (15 and 17) (Figure 2-65) (1- and 31-speed), and the "Y" yoke (10).

Gear Housing. The gear housing (16) consists of an aluminum alloy casting which contains the azimuth gear train and bearings for supporting the hollow shaft forming the base of the "Y" yoke. Also located on the gear housing are the computer standby switch (11) (Figure 2-64), reticle adjustment rheostat (10), azimuth friction screw (14) (Figure 2-65), position-out switch (1) (Figure 2-67), and inertia wheel assembly (3).

Azimuth Gear Train

A spur gear (22), keyed to the end of the "Y" yoke shaft engages in identical spur gear (24) attached to the end of the 1-speed Selsyn generator rotor shaft. As the "Y" yoke (12) is rotated in azimuth, the 1-speed Selsyn (15) rotor makes one revolution for every revolution of the yoke. The spur gear (24) on the rotor shaft of the 1-speed Selsyn engages a pinion gear (16) on a shaft supported between bearings in the gear housing. Keyed to the opposite end of this shaft is a large spur gear (19) which engages a pinion gear (17) attached to the rotor shaft of the 31-speed Selsyn generator (15). The gear ratio of this gear train is such that the rotor of the 31-speed Selsyn makes 31 revolutions for each revolution of the "Y" yoke. (Figure 2-66.)

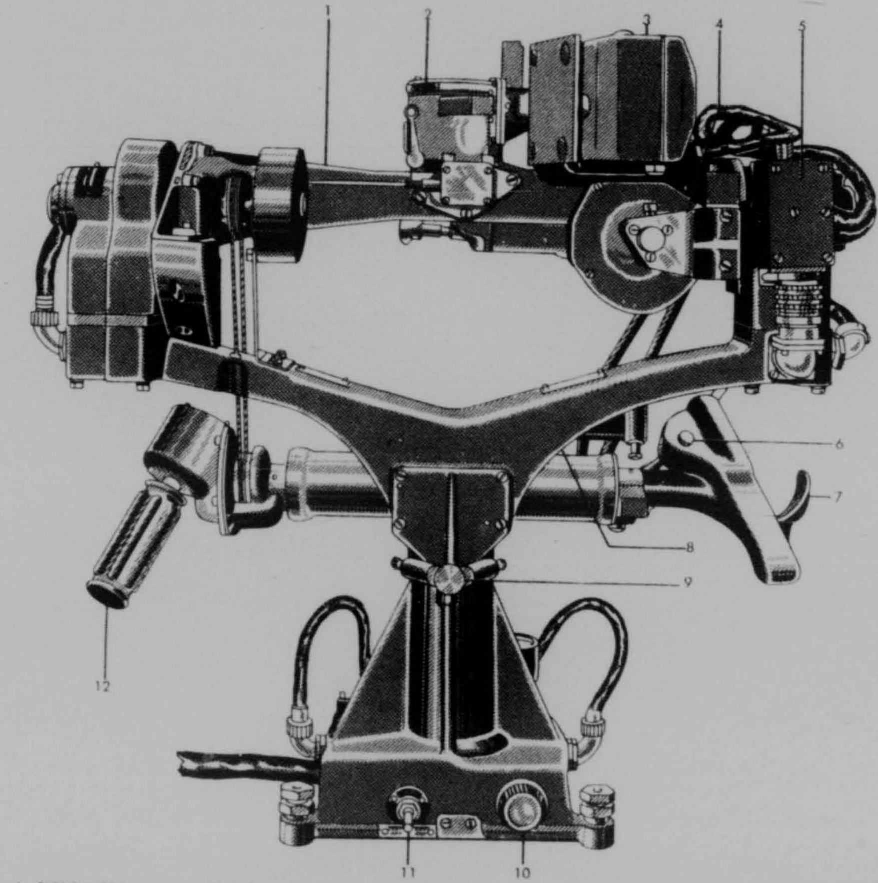
Inertia Wheel Assembly

The inertia wheel (20) is driven by a pinion gear (18) meshing with the same large intermediate spur gear (19) that drives the gear

on the 31-speed Selsyn rotor. The flywheel effect tends to smooth out the rate of motion of the sighting station as it is moved in azimuth.

Position-out Switch

This switch (23) (Figure 2-66) is located in the gear housing under the spur gear (22) on the end of the "Y" yoke shaft. It is operated by a cam (21), on the underside of the spur gear, when the sighting station is more than 100 degrees aft of the broadside position and cuts off control power to the turret. The D1 model switch cam is located on the opposite side of the spur gear from the D2 model. Thus, if the action switch is closed when the sighting station is in a position to cause the posi-



1. SIGHT YOKE
2. RETIFLECTOR SIGHT
3. CAMERA
4. GYROSCOPE
5. JUNCTION BOX
6. INTERPHONE SWITCH
7. ACTION SWITCH
8. "Y" YOKE
9. AZIMUTH STOW PIN
10. RETICLE RHEOSTAT
11. COMPUTER STANDBY SWITCH
12. RANGE GRIP

Figure 2–64. Gunner's Side View of Yoke Sighting Station, Models 2CSR4D1 and 2CSR4D2.

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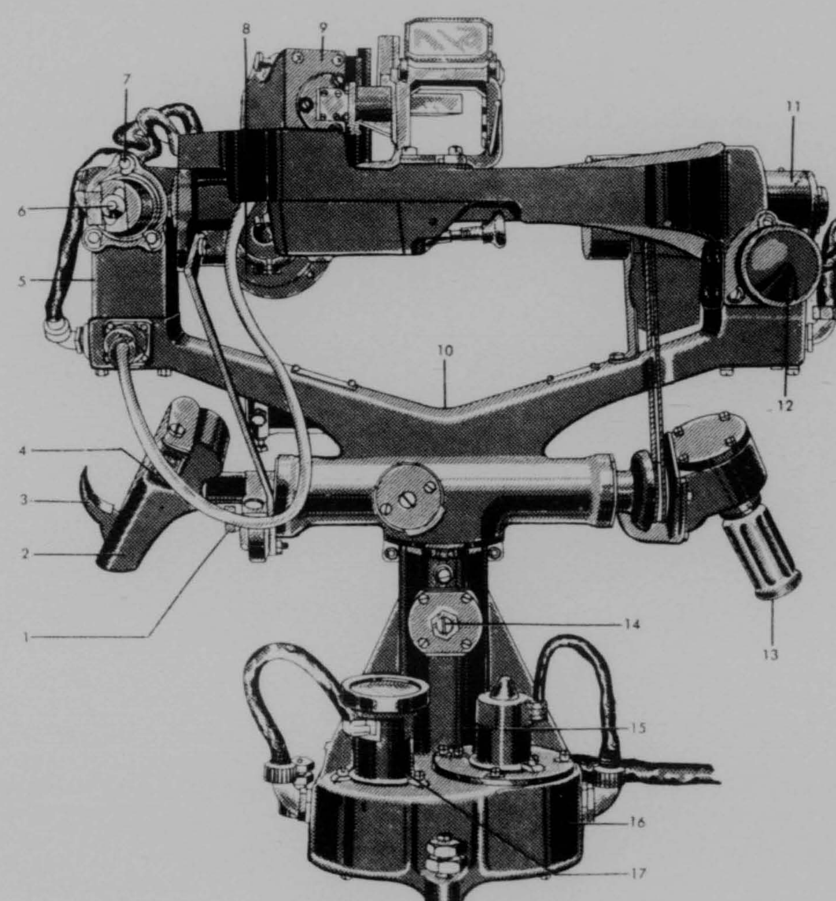
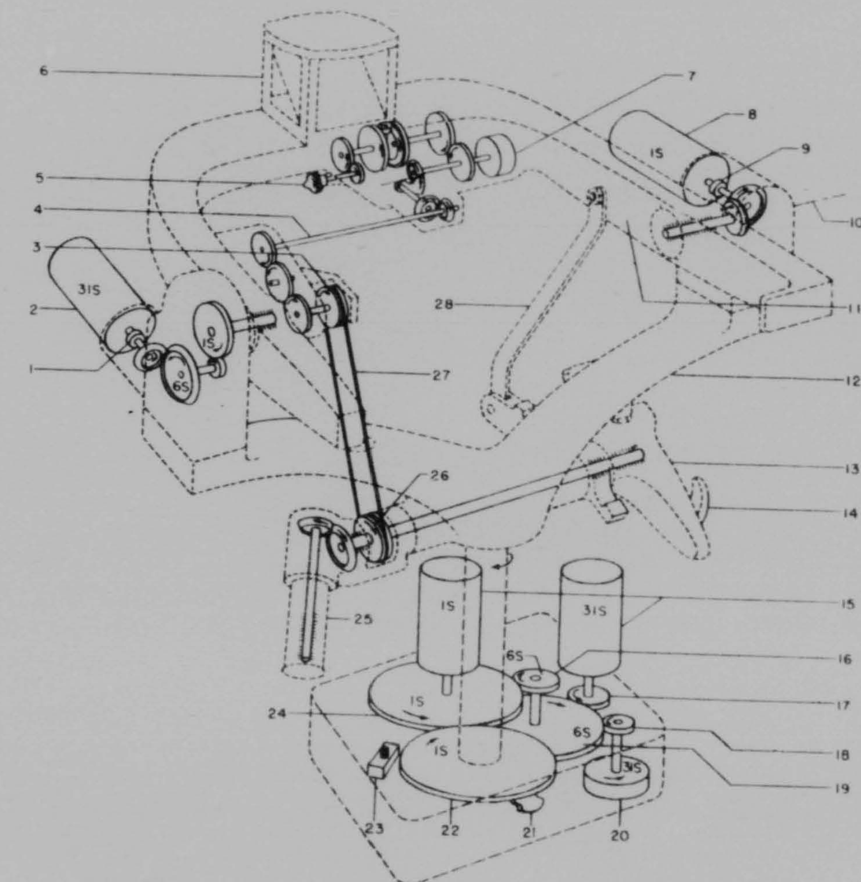


1. ELEVATION STOW PIN
2. FIRING GRIP
3. ACTION SWITCH
4. FIRING TRIGGER
5. ONE-SPEED ELEVATION UNIT
6. ONE-SPEED ELEVATION SELSYN
7. CLAMPING SCREW
8. GYROSCOPE
9. CAMERA
10. "Y" YOKE
11. 31-SPEED ELEVATION UNIT
12. 31-SPEED ELEVATION SELSYN
13. RANGE GRIP
14. AZIMUTH FRICTION SCREW
15. ONE-SPEED AZIMUTH SELSYN
16. AZIMUTH GEAR HOUSING
17. 31-SPEED AZIMUTH SELSYN

Figure 2–65. Overall Rear View of Yoke Sighting Station.



1. Adjustable coupling
2. 31-speed elevation selsyn
3. Upper sheave
4. Flexible shaft
5. Target input knob
6. Retiflector sight
7. Potentiometer
8. 1-speed elevation selsyn
9. Adjustable coupling
10. Pivot
11. Sight yoke
12. "Y" yoke
13. Firing grip
14. Action switch
15. Azimuth selsyn generators
16. Pinion gear
17. 31-speed selsyn pinion gear
18. Pinion gear
19. Intermediate spur gear
20. Inertia wheel
21. Cam
22. Yoke spur gear
23. Position-out switch
24. 1-speed selsyn spur gear
25. Range grip
26. Lower sheave
27. Cable
28. Link

Figure 2–66. Schematic Diagram of Yoke Sighting Station Gearing.

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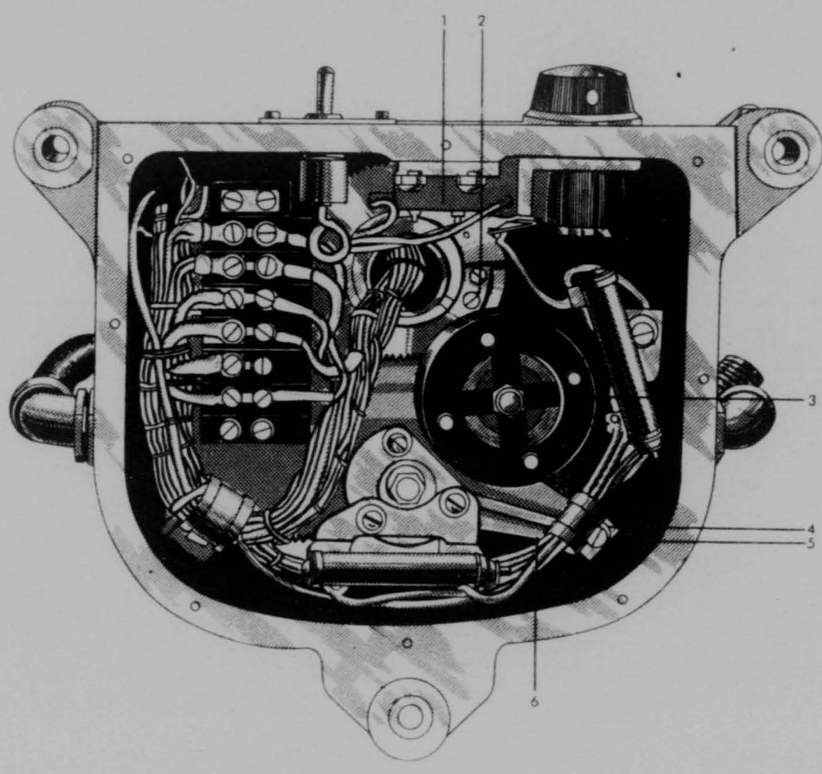


1. POSITION-OUT SWITCH
2. CAM
3. INERTIA WHEEL ASSEMBLY
4. LOCK WASHER
5. SCREW
6. BEARING SUPPORT

***Figure 2—67.* Bottom View of Azimuth Unit, Cover Removed.**

tion-out switch to be operated, the turret will not be brought under control of the sighting station and will not attempt to synchronize with the sighting station. The purpose is as follows: when the action switch is open, the turret automatically moves to its stowed position. If the action switch is closed when the position-out switch is not in its operated position, the turret will synchronize with the sighting station position. An inherent feature of the control system is that the turret will attempt to move through the shortest arc to align with the sighting station. If there were no position-out switch and the turret were more than 100 degrees aft of broadside when the action switch was closed, the turret would attempt to synchronize by moving forward until hitting the forward stops and would remain there until the sighting station were moved to a position less than 80 degrees aft of broadside. Under the above conditions, the position-out switch insures that the turret will remain in the stowed position until the sighting station is less than 100 degrees aft of broadside, instead of only 80 degrees, and

then will move into correspondence with the sighting station.

Selsyn Generators

These units (Figure 2-65) are mounted vertically on the gear housing (16) opposite the "Y" yoke shaft (10) from the gunner. A flange on the shaft end of each Selsyn fits snugly into a recess in the gear housing. Three clamps held by lock washers and screws, which fit into tapped holes in the gear housing, fit over the edge of the flange on each Selsyn. These clamps may be loosened to permit zeroing the Selsyns.

Computer Standby Switch

This toggle switch (11) (Figure 2-64) is mounted on the front of the azimuth unit gear housing. The switch allows the Selsyn signal from the sighting station to by-pass the computer and go directly to the control-transformers on the turret. Thus it can make the system noncomputing, if the computer is damaged by gunfire.

Azimuth Friction Screw

This assembly (14) (Figure 2-65), located on the neck of the gear housing opposite the gunner, adjusts the ease with which the sight may be rotated in azimuth. Tightening or loosening the screw increases or decreases the friction on the rotating shaft of the "Y" yoke.

Azimuth Stow-pin

The azimuth stow-pin assembly (9) (Figure 2-64), located in front of the gunner between the azimuth limit stops on the base of the "Y" yoke, fits into a recess in the neck of the azimuth unit gear housing. It stows the sight broadside in azimuth. A ball, spring, and limit screw assembly hold the pin in its "out" or "in" position.

Azimuth Limit Stops

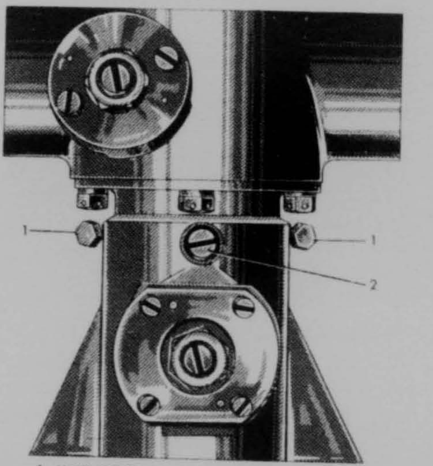
Two limit stops (1) (Figure 2-68), which consists of two adjustable screws with lock nuts, are installed in the stow pin bracket which is attached to the gunner's side of the "Y" yoke. The stops strike against a bumper (2), attached to the azimuth gear housing, when the azimuth travel limit is reached. To limit the azimuth travel of each sighting station more in the aft quadrant of operation than in the forward quadrant, a longer limit stop is provided in the forward side of the stow pin bracket. Minor adjustments of the travel limits are made by loosening the lock nut and turning the stop screws in or out, as required.

Electrical Connections

Electrical connections for incoming power and outgoing signals are made through a connector and cable entering the base of the azimuth unit on the left side. Power is brought into the rotor and taken off the stator of each azimuth Selsyn through cables extending from the sides of the gear housing to each Selsyn cap. Conections to those units mounted on the "Y" yoke and the sight yoke are made through the hollow shaft and arms of the "Y" yoke to connectors on the ends of the arms.

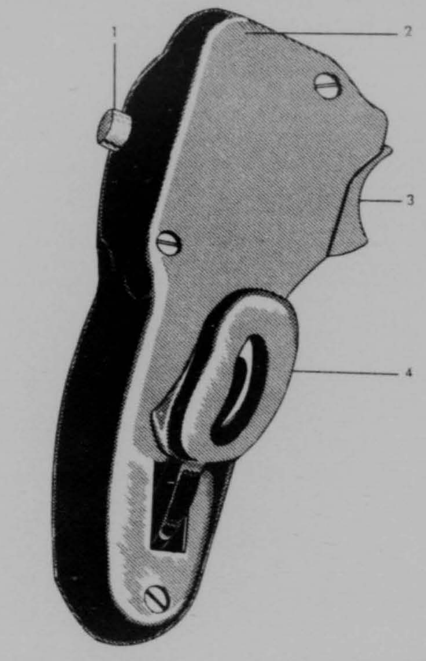
"Y" Yoke

This unit is a Y-shaped hollow, aluminum alloy casting (10) (Figure 2-65) which is supported by a hollow shaft mounted in bearings



1. LIMIT STOPS 2. BUMPER

Figure 2—68. Closeup View of Azimuth Bumpers and Stops.



1. INTERPHONE SWITCH
2. FIRING GRIP
3. FIRING TRIGGER
4. ACTION SWITCH

Figure 2–69. Closeup View of Firing Grip.

located in the neck of the azimuth gear housing (16). Mounted on the "Y" yoke are the firing grip (2), range grip (13), elevation 1-speed unit (5), elevation 31-speed unit (11), gyro-and-camera junction box (5) (Figure 2-64), elevation limit stops and stow pins (9) (Figure 2-64) and (1) (Figure 2-65).

Firing Grip

The right-hand grip (2) (Figure 2-69) is the firing grip and contains an action switch (4), the firing trigger (3), and an interphone switch (1). The action switch (4), which applies power to the turret, is held closed against a spring as the gunner depresses the switch lever with the side of his hand. The gunner's hand fits between the grip and the lever—not over the lever. The trigger (3), located at the top of the grip, is operated by the first, or index finger. The interphone switch (1) is a push button which is operated by the thumb.

Range Grip

The left-hand grip (25) (Figure 2-66) is the range-adjusting grip. Gearing connects the grip to a sheave cable (27) which, through additional gearing on the sight yoke (11), is connected to a flexible shaft (4). The flexible shaft, is, in turn, connected by gearing to the retiflector sight (6).

One-speed Elevation Unit

The 1-speed elevation unit (5) (Figure 2-65) is located on the end of the right-hand arm of the "Y" yoke. It contains the gearing connecting the sight yoke with the 1-speed elevation Selsyn generator, and a bearing supporting the end of one arm of the sight yoke. A bevel gear, pinned to the end of a shaft attached to the sight yoke (11) (Figure 2-66) and supported by a bearing in the 1-speed elevation unit, engages an intermediate spur gear. On the shaft with the spur gear is a bevel gear which engages a bevel gear pinned to a shaft which, in turn, is connected by an adjustable coupling (1) to the 31-speed elevation Selsyn generator rotor shaft. The gear ratio of this train is such that the rotor of the 31-speed Selsyn generator would, if the limit stops of the sighting station permitted, make 31 complete revolutions for each revolution of the hand grips.

Gyro and Junction Box

This assembly (5) (Figure 2-64) is mounted by a connector on the end of the right arm of the "Y" yoke (8). It serves as a central distributing and collecting point for the gyroscope and camera circuits. A camera "on-off" switch is mounted in the box.

Elevation Limit Stops

The elevation-stop bumpers located on the shaft of the firing grip, move with the grip as it is turned in elevation and bear against the stop assembly, located on the "Y" yoke, to limit the elevation motion of the sight. Minor

adjustments in elevation travel can be made by loosening the lock nuts and turning the stop screws in the face of the stop in or out.

Elevation Stow-pin

The elevation stow-pin (1) (Figure 2-65) located near the stop bumpers, fits into a machined recess in the "Y" yoke. It stows the sight in a horizontal position. A ball, spring, and limit screw assembly, hold the pin in its "out" or "in" position.

Elevation Clamp

This assembly, located on the 1-speed elevation unit, adjusts the ease with which the sighting station may be rotated in elevation. Tightening or loosening the screw increases or decreases the friction on the shaft of the right-hand arm of the sight yoke. The clamp can be used to lock the sight yoke in any elevation position during maintenance of the sighting station.

Sight Yoke

In order to minimize the amount of movement required by the gunner in tracking a target in elevation, that retiflector sight (2) (Figure 2-64) is mounted on the closed end of the sight yoke (1) which is, in turn, supported, at its open ends, between the elevation units on the open ends of the "Y" yoke (8). Shafts, pinned to the sight yoke, are mounted in bearings in the elevation units which permit the gunner to pivot the sight yoke, and thus the sighting station, in elevation. A camera (3) and gyroscope (4) are mounted on the right arm of the sight yoke. Model 2CSR4D1, serial No. 4291836 through 4291837, and 4314760 through 434785, inclusive, and model 2CSR4D2, serial No. 4291834 through 4291835, and 4414538 through 4414563, inclusive, are each equipped with a counterweight (33) (Figure 2-70) which is attached to the end of the left arm of the yoke. This counterweight, together with a counterspring which is attached to the sheave-and-gear assembly (14) (Figure 2-70) and which is supported by a bracket mounted on the "Y" yoke, counterbalances the weight load of the yoke and its attached equipment. All other yoke sights are not equipped with a counterweight; instead, a stronger counterspring is provided to counterbalance the weight load of the yoke and its attached equipment. The yoke is connected by a mechanical link (28) (Figure 2-66) to the right-hand grip which moves the sighting station in elevation as the hand grips are turned in elevation.

Gyroscope

Each upper sighting station has one free gyroscope (4). It is mounted on the sighting station to furnish the computers with sight movement in azimuth and elevation. (Figure 2-64)

Retiflector Sight

The retiflector sight (2), mounted on the closed end of the sight yoke, uses a DC range signal.

Camera

The camera assembly (3), with the exception of the camera adapter lens, is government furnished equipment, U. S. Army Specification No. 75-366. It is mounted on the sight yoke adjacent to the retiflector sight and is used to make a permanent record of combat action.

Camera Components

The camera is the 16-mm type with a magazine containing fifty feet of film. The standard speed is sixteen frames per second although speeds of thirty-two and sixty-four frames per second are obtainable by setting the camera speed knob. Pictures are taken through the sight reflecting glass by means of a special periscope-type camera adapter lens.

Camera Operation

When the gunner presses his firing trigger the camera action starts. The camera records the target, reticle image, retiflector target size, and the range distance. An overrun control continues the picture action, for a limited period, after the gunner has released his firing trigger.

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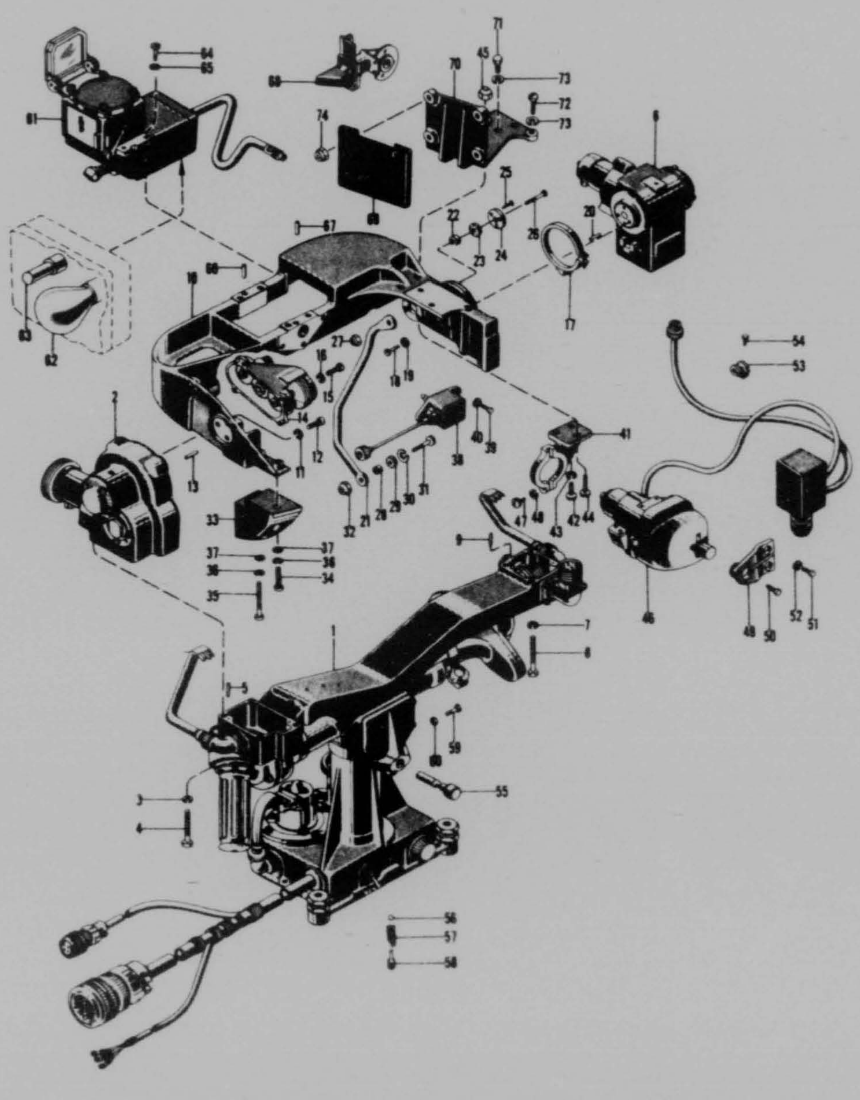


Figure 2—70. Exploded View of Yoke Sighting Station, Models 2CSR4D1 and 2CSR4D2.

Camera Adapters

The sighting stations use camera adapters which enable cameras located adjacent to the retiflector sight to photograph the target as it appears on the sight retiflector plate. The adapters, which are miniature periscopes, mount on the camera. On the yoke sighting station, the adapter extends from the camera in a vertical plane to the retiflector sight. The adapter has an adjustable light opening which must be set for speeds and for light conditions.

3. DETAILED DESCRIPTION OF SELSYNS

A Selsyn is a small self-synchronous instrument used as an electrical means of transmitting data concerning the relative angular positions between two or more remotely located devices. In the remote-control turret system, Selsyns are used to transmit the angular position of the sight and guns.

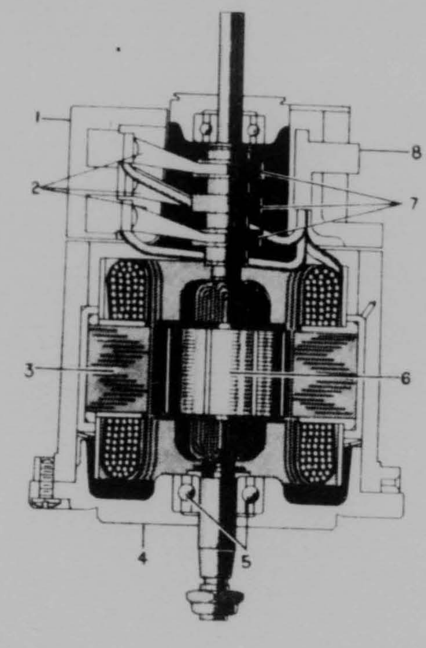
Selsyn Generator Model 2J15A1

The Selsyn generator is mechanically a miniature bipolar, rotating field, three-phase alternator. The rotor is wound with a single-phase, concentrated winding; the stator with a three-phase, distributed "Y"-connected winding.

Electrically the Selsyn acts as a transformer, and voltages and currents are single phase. The rotor is excited by an alternating voltage source, one phase of the aircraft's three-phase, 400-cycle supply. By transformer action, voltages are induced into the three stator windings, the magnitude of the voltage in each depending upon the angular position of the rotor.

Mechanically the Selsyn generator consists of a stator carrying a three-coil winding, a rotor carrying a single winding which revolves inside the stator, an end shield forming part of the housing for the elements, and a connector for making electrical connections with the Selsyn (Figure 2-64).

The stator (3) (Figure 2-71) consists of three windings assembled within a slotted, laminated core which is fitted into the end



1. Collector end shield
2. Brushes
3. Stator
4. End shield
5. Ball bearings
6. Rotor
7. Collector rings
8. Connector

Figure 2—71. Sectional View of Selsyn Generator, Model 2J15A1.

shield (1). A lead from one end of each of the three windings extends to contacts (identified as "S_1", "S_2", and "S_3"), carried by the connector (8). The other ends of the three stator windings are connected internally in the Selsyn.

The rotor (6) of the Selsyn generator consists of a single coil wound on a laminated iron core. Opposite end of the rotor are supported in ball bearings (5) carried by the two end shields. The ends of the rotor winding are brought out to spaced collector rings (7) mounted on the rotor shaft. Brushes (2), electrically connected to contacts on the connector, ride on the collector rings providing an electrical connection to the rotor. The contact pins connected to the brushes are identified as "R_1" and "R_2".

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The rotor of the Selsyn generator is energized by 400-cycle AC from one phase of the aircraft's three-phase supply source. This produces a magnetic flux in the rotor winding which, in turn, and by transformer action, produces a voltage in each of the three windings of the stator. The rotor is geared to the sighting station so that as the sight is moved manually, the rotor likewise moves, varying the voltage induced into the stator coils.

4. PRINCIPLES OF OPERATION

The Yoke Sighting Station

The yoke sighting station is of the retiflector type and the gunner moves it manually in both azimuth and elevation. The Selsyn follow-up system provides the means of indicating the position of the sight to the turret. In operating the sighting station, the gunner grips both the range grip and the firing grip and moves the sighting station manually in elevation and in azimuth. To enlarge the gunner's field of vision, the sighting station is bolted to a plate which is, in turn, so attached to the airplane's structure that it allows the sighting station to protrude into the stationary, transparent blister.

The Selsyn System

The azimuth and elevation Selsyn generators located on the yoke sighting station send a signal corresponding to the sight position to the Selsyn control transformers located on the turret. Located electrically between the Selsyn generators on the sighting station and the Selsyn control transformers on the turret are the computer differential Selsyns. When no computer correction is necessary, the position signal from the sight is transmitted electrically to the control transformer unchanged. Corrections result in the sight position signal being modified by the addition of the correct correction angle. This new position signal is then sent on to the control transformers. The guns then point in the direction indicated by the sighting station plus or minus the correction angle determined by the computer.

The Free Gyro System

The gyro is used to indicate to each computer the angle traversed by the target during the prediction computing time interval. Specifically, the gyro is used in the computing circuit to predict the lead correction necessary for advancing the guns ahead of the target by an amount proportional to the range and relative speeds of the ownship and target. The gyro does this by very accurately measuring the angle traversed by the target during the prediction computing time interval. The free gyroscope is so named because it is free to move in any direction within approximately 15 degrees of the gyroscope axis. The motor shaft axis of the gyro is parallel to the line of sight. The caging mechanism end points toward the target. As the sight moves, the entire gyro moves with it so that the motor shaft always points along the line of sight. When the firing trigger on the sighting station is pressed, a solenoid in the gyro is energized and the caking cone is drawn away from the gyro motor frame. The housing will continue to move with the sighting station, but the motor shaft will stay pointing in the same direction it did at the instant it was uncaged.

The Retiflector Sight

The retiflector sight is a direct-vision type optical sight which is so constructed that when the gunner properly adjusts the circle of light to span his target, the sight through its accessory equipment transmits an indication of range, and because of its rigid mounting to the sighting station, indirectly transmits azimuth and elevation to the computer.

Camera and Camera Adapter

The camera is mounted adjacent to the retiflector sight and is used to make a permanent record of combat action. When the firing trigger on the sighting station is pressed, the camera action starts. The camera records the target, the reticle image, retiflector target size, and records the size of the reticle image so as to give an approximation of the range distance. An overrun control continues the picture action for a limited period after the gunner has released his firing trigger. In order to enable the camera, which is adjacent to the retiflector sight, to photograph the target as it appears on the sight retiflector plate, the

sighting station makes use of a camera adapter. The adapter is a miniature periscope and is mounted on the camera.

Installation of Elevation Selsyns

Installation of the elevation Selsyns is as follows: The coupling hub is installed on the shaft of the Selsyn-and-adapter assembly and secured with the lock nut. The tooth is positioned on the Selsyn coupling hub so that it will fit into the slot of the Selsyn nut and seat the Selsyn in the elevation unit housing.

The three Selsyn clamps, lock washers and screws are replaced.

The clamps are adjusted to engage the flange of the Selsyn casing and the clamps are tightened in position.

Installation of Retiflector Sight

The three Selsyn clamps, lock washers and (The sight or gyroscope should not be installed until the backlash tests and adjustments have been made. The sight should be tested in accordance with the instructions set forth in the instruction book AN 11-70AA-42 before installation.)

The sight assembly is mounted on the sight yoke. The sight is aligned on the yoke by two dowel pins and fastened to the yoke with the four screws and lock washers.

The electrical connector is attached to the rear receptacle on the 1-speed yoke arm.

Installation of Bevel Gear Support and Shaft

The bevel gear support and shaft are installed as follows:

The bevel gear support-and-shaft are mounted on the sight yoke and secured with four screws and lock washers.

The range grip is rotated until the cable clamps on the lower sheave are above the sheave shaft and in an approximately horizontal position. The nut is threaded and fastened on the end of the flexible cable to the hub inclosing the splined shaft of the sheave-and-gear assembly. Fastening the flexible cable to the splined shaft with the cable clamps in this position insures the widest possible range swing of the retiflector sight. Minor adjustments can be made after the retiflector sight is installed and the sighting station operated.

Installation of the Gyro

The gyro is installed on the sight yoke as follows:

The rear gyro bracket is fastened to the underside of the sight yoke with two screws and lock washers and the longer screw and nut, which also aids in securing the camera bracket.

The gyro is slipped into its rear bracket. Supporting the gyro with one hand the front bracket is fitted to the sight yoke with the two screws and lock washers.

The three screws which secure the front bracket to the gyro, and the clamping screw on the rear gyro bracket, are tightened.

The gyro junction box to the forward receptacle on the yoke arm.

Installation of Camera and Camera Adapter

The camera and camera adapter are installed as follows:

The camera mounting bracket is replaced on the top of the sight yoke and fastened with the screws and lock washers. The nut is threaded and tightened on the screw to fasten both the gyro bracket and the camera mounting bracket.

The camera and the camera guard are assembled to the side of the camera mounting bracket and the camera secured to the guard and bracket with four nuts.

The camera adapter lens assembly, if it has been removed, is replaced.

SECTION V—TAIL TURRET

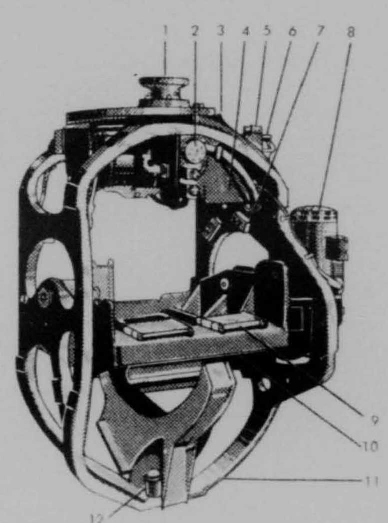
1. GENERAL

The tail turret, model 2CGD20TRB1, is approximately spherical when the enclosure is mounted on it. Its diameter at mid-section is 40 inches and its overall height is 40⅞ inches. It travels 45 degrees each side of straight aft in azimuth and the two 20-mm guns travel 40 degrees above or below centerline. The guns move in elevation independently of movement in azimuth.

Basic assemblies comprising the tail turret are described in detail in the following paragraphs.

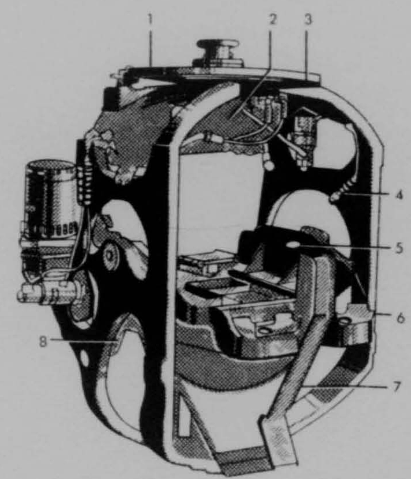
Gimbal Assembly

The gimbal assembly (11) (Figure 2-72)



1. UPPER TRUNNION
2. CONNECTOR
3. AZIMUTH STOP AND ARM
4. TERMINAL BOARD
5. AZIMUTH STOP
6. AZIMUTH LIMIT SWITCH
7. ELEVATION STOP
8. ELEVATION DRIVE
9. REAR GUN SUPPORT
10. SADDLE
11. GIMBAL
12. LOWER TRUNNION

Figure 2–72. Forward View of the Tail Turret with Enclosure and Guns Removed.



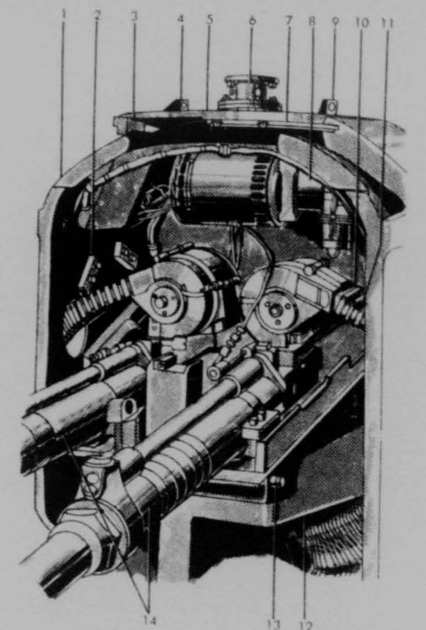
1. PLATE
2. AZIMUTH DRIVE
3. AZIMUTH GEAR SECTOR
4. ELEVATION LIMIT SWITCH
5. SHAFT
6. FRONT GUN SUPPORT
7. SHELL CHUTE
8. ELEVATION GEAR SECTOR

Figure 2–73. Aft View of the Tail Turret.

is the main framework of the tail turret on which all other parts of the turret proper are mounted. It rotates in azimuth on upper (1) and lower trunnions (12), located at the top and bottom of the gimbal. The azimuth stop (5) and azimuth limit switches (6), mounted on the gimbal, limit travel in azimuth of the turret. The elevation stop assemblies (7) and limit switches (4) (Figure 2-73), also mounted to the gimbal, limit travel in elevation of the saddle (10) (Figure 2-72) and the guns. The terminal board (4) and connector assembly (2) are also mounted on the gimbal assembly.

Plate and Sector Assembly

This assembly (1 and 3) (Figure 2-73), located above the gimbal, is held stationary to the airplane structure by the upper trunnion



1. GIMBAL
2. ELEVATION STOP
3. AZIMUTH STOP
4. ANTI ROTATION BRACKET
5. PLATE
6. UPPER TRUNNION
7. AZIMUTH GEAR SECTOR
8. AZIMUTH DRIVE
9. ANTI ROTATION BRACKET
10. AMMUNITION CHUTE
11. ELEVATION LIMIT SWITCH
12. SADDLE
13. FRONT GUN SUPPORT
14. GUNS

Figure 2–74. Tail Turret with Guns Mounted.

(6) (Figure 2-74) aided by two antirotation brackets (4 and 9). The azimuth drive unit (8) engages the gear sector (7), bolted to the plate (5), to drive the turret in azimuth. Azimuth stops and stop arms (3) (Figure 2-72) are fastened to the plate.

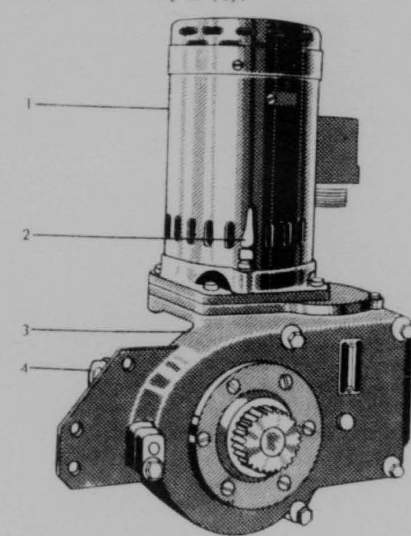
Saddle Assembly

The saddle assembly, supported on the gimbal by two steel shafts (5) (Figure 2-73), is a magnesium casting on which the two 20-mm guns are mounted by front and rear gun supports. The two front gun supports (6), bolted to the saddle, can be adjusted to move the guns horizontally. The two rear gun-slider mounts (9) (Figure 2-72), fastened to brackets which are bolted to the saddle, provide vertical adjustment of the guns. This adjusts the alignment of the gun bore. The elevation gear sector (8) (Figure 2-73) bolted to the side of the saddle is engaged by the elevation drive pinion to move the saddle and guns in elevation.

Azimuth and Elevation Drive Assemblies

The drive assemblies for movement of the tail turret in azimuth and in elevation are identical. For simplicity the following description will be of the azimuth-drive assembly as used for positioning the turret in azimuth.

Function. The azimuth drive (Figure 2-75) performs two functions. It supplies the mechanical power required to drive the turret and guns in azimuth and it provides electrical equipment which assists in controlling the position of the turret and guns in azimuth. The three main units of the azimuth assembly are the drive motor (1), the gear assembly (3), and the Selsyns (4).



1. MOTOR
2. BRAKE RELEASE
3. GEAR ASSEMBLY
4. SELSYN CONTROL TRANSFORMERS

Figure 2–75. Azimuth and Elevation Drive.

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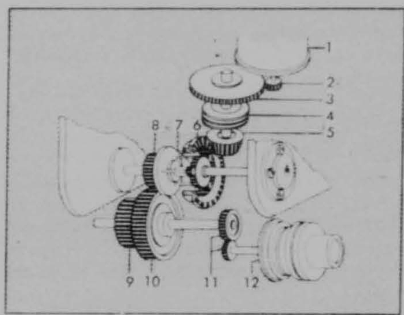

1. MOTOR
2. MOTOR PINION
3. GEAR
4. CLUTCH ASSEMBLY
5. BEVEL PINION
6. BEVEL GEAR
7. PLANETARY GEARS
8. SPUR GEAR
9. MAIN DRIVE GEAR
10. SPUR GEAR
11. SELSYN DRIVE GEARS
12. SELSYN CONTROL TRANSFORMERS

Figure 2–76. Schematic of the Azimuth and Elevation Drives.

Drive Motor. The drive motor rated at ½ horsepower, is a separately-excited motor which rotates either clockwise or counter-clockwise according to the signal from the thyratron power supply. The input voltage from the thyratron power supply controls the motor speed. A solenoid-operated brake, located at the base of the motor, prevents rotation of the drive-motor armature when the motor is not energized. When the motor armature is locked by the brake, the turret cannot rotate in azimuth. The brake is applied automatically when the AN APG-3 radar antenna moves beyond the azimuth limit of the guns. This de-energizes the solenoid, thus engaging the brake and holding the turret against the limit stop. When the radar antenna is again moved back within the limits of gun travel, the brake is automatically released. The brake can be released manually by two spring-loaded levers (2), one located on each side of the motor.

Gear Assembly. (Figure 2-76.) Power is transmitted from the drive motor (1) through a power gear train to the azimuth gear sector as follows: The motor pinion (2) meshes with the large gear (3) of the clutch assembly (4).

A bevel pinion gear (5) on the clutch shaft meshes with a large bevel gear (6) which also serves as the drive gear of a planetary gear system.

The small spur gear (8), attached to the driven portion of the planetary gear system, is meshed with a large gear (10) on the main-drive-gear shaft. The main drive gear (9) meshes with the azimuth sector gear, driving the turret either clockwise or counterclockwise. The gears (11) connect the Selsyns (12) to the main drive shaft. The clutch assembly (4) protects the gear train from excessive shocks when the guns reach their maximum azimuth limits.

Selsyns. The Selsyn used on the drive assembly is the tandem model and is geared to the main-drive shaft. The tandem Selsyn embodies both the 1-speed and the 31-speed units in one case. The shaft of the 31-speed rotor extends outside the case and is geared to the main-drive shaft (Figure 2-76). As the name implies, the 31-speed unit would revolve 31 times if the turret were to make one complete revolution. An internal planetary gear system, located between the 31-speed and the 1-speed units, reduces the speed of the 1-speed rotor so that it would make one revolution if the turret were to revolve 360 degrees.

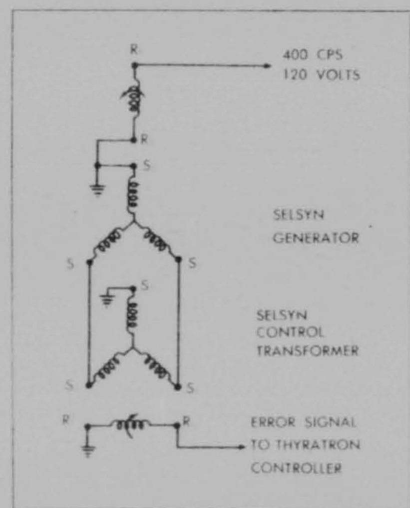

Figure 2–77. Elementary Wiring Diagram of the Selsyn Circuit.

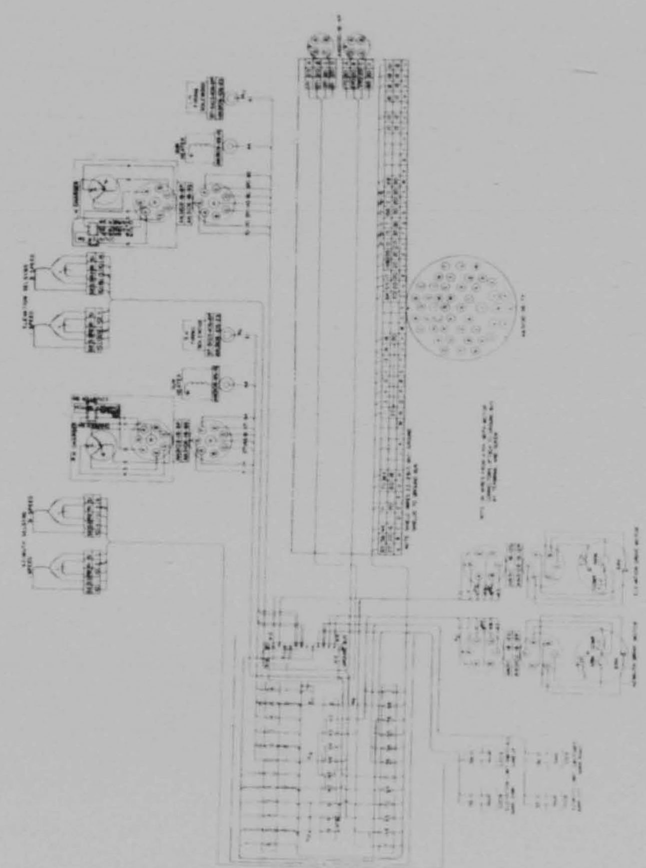

Figure 2–78. Wiring Diagram of the Tail Turret.

Each Selsyn control transformer consists of the following basic elements: a stator, a rotor, an end shield, and a connector. The voltage on the rotor of the Selsyn control transformer is rated at 120 volts. Electrical connections to the Selsyn control transformer are made through connector contacts identified by R1, R2, S1, S2, and S3. The three stator windings of the control transformer are electrically connected through system wiring to the stator windings in the Selsyn generator so that the voltages appearing in the windings of the Selsyn generator are reproduced in magnitude and polarity in the stator windings of the control transformer (Figure 2-77). The resulting magnetic flux in the control-transformer stator induces a voltage in the rotor by transformer action which is the signal voltage fed to the thyratron controller. This signal indicates the difference between the line of sight of the radar and the line of sight of the guns.

2. PRINCIPLES OF OPERATION

Electrically, the turret is made up of three major systems: the Selsyn system, the limit-switch, and drive-motor system, and the firing system. Each of these systems will be dealt with briefly (Figure 2-78).

The control transformers are connected directly to the Selsyn generators in the AN/APG-3 radar antenna unit. As long as the radar antenna is scanning, the Selsyns are inoperative. The Selsyn system is in operation, however, when the radar is tracking a target airplane. (Reference may be made to the handbook of operating instructions for the radar antenna unit for further information concerning the fire-control tie-in between the tail turret and the radar antenna unit.) Input voltage to the turret Selsyns is called the signal voltage from the radar antenna Selsyns. Output voltage from the turret Selsyns is called the error signal. The error signal is proportional to the difference in direction in which the radar antenna and the turret are pointing. The error signal from the turret Selsyns is fed to the thyratron controller where it is amplified and then returned as a DC voltage to the armature of the azimuth drive motor. The turret is then driven by the azimuth drive motor in such a direction as to realign the turret azimuth Selsyn rotor with the stator so that the error signal across the rotor is reduced to zero voltage.

The Limit-switch and Drive-motor System

The azimuth and elevation limit switches are protective devices which cut off DC power to the drive-motor circuits when the turret has reached the limits of movement in azimuth and in elevation. The 27-volt bus in the thyratron controller is connected to the turret safety switch in the junction box. From this switch the line is connected to circuit breaker CB-5 in the control panel. The circuit breaker in turn is connected to line 143 which is divided into two voltage paths. Line 143 is connected to the fields of both the elevation and the azimuth drive motors to ground. Line 143 is connected also to the turret limit relays in the thyratron controller, and through these relays emerges as lines 55, 56, 155, and 156 to the azimuth and elevation limit stops to ground. If, for instance, the turret reaches its elevation limit in one direction, one of the elevation limit switches opens. If it is switch S209 which opens, relay K108 in the thyratron controller becomes de-energized. Immediately, the brake coil in the elevation motor is de-energized, and the brake is momentarily applied. The backout relay K213 in the thyratron controller is de-energized and 27 volts is again applied to the brake coil in the motor, energizing the coil and releasing the brake. The motor is, therefore, prepared to rotate in the opposite direction should voltage from the thyratron controller of the proper polarity and value be supplied to the armature across lines 17 and 18. The azimuth drive circuit is identical to the elevation drive circuit and operates according to the same principles.

The Firing System

The gun heaters are supplied with 115 volts, 400 cycles through line 44 when the uni-switch on the control panel is in the warm-up position. The firing solenoids are energized by 27 volts DC through line 61. The gun-charger and booster motors are connected in parallel. These motors are energized when relays K26

and K27 in the junction box are energized. Lines 170, 270, 370, and lines 171, 271, and 371 supply 208 volts, 400 cycles to the chargers and the booster motors. Lines 80 and 81 are the thermal overload lines to ground on the charger motors.

SECTION VI—B-36 HEMISPHERE GUN SIGHT

1. INTRODUCTION

These preliminary engineering instructions contain technical information on the General Electric Model 2CSH4A2 hemisphere sighting station manufactured by the Farrand Optical Co., Inc. The sight is used with the General Electric Remote Control Turret System in both the YB-36 and B-36 airplanes.

The hemisphere sighting station enables the gunner to control the nose turret. Component parts of the system are (1) the hemisphere sight (2) the desiccator unit.

Function

The hemisphere sight is the controlling unit of a system that aims and fires the nose turret guns of the airplane in which it is mounted. The sight is operated by a gunner stationed beneath the turret. As the gunner moves the sight the turret guns are automatically positioned in aim to agree with the line of sight the gunner has selected through the eyepiece. This relation is accomplished by Selsyn circuits, which are regulated by the movement of the sight mechanism and control the aiming operations of the guns.

Description

The hemisphere sight is a stationary periscope, mounted horizontally in the nose of the airplane so that its spherical glass dome head projects through the nose structure. The sight is shock-mounted in its supports. At the head end the sight is supported in a cylindrical nose fitting, at the eyepiece end by means of vertical and lateral support rods. Rotation of the hand-control-grips serves to position the scanning prisms located in the prism head. The target is followed in azimuth by rotating the control grips about its horizontal axis. The guns are fired by actuating an action and trigger switch mounted on the left control grip. The ranging mechanism is controlled by a squeeze-grip lever located on the right control grip. A desiccator pump unit is mounted

Characteristics

The hemisphere sighting station has the following characteristics:

Dimensions:	Length: 48 inches Maximum Height: 22 inches Maximum Width: 23 inches
Weight:	150 lbs.
Sighting Limits:	Right Azimuth: 90 degrees Left Azimuth: 90 degrees Elevation: 90 degrees Depression: 90 degrees
Line of Sight-Stow Position:	Azimuth: 0 degrees Elevation: 0 degrees (+) 30 degrees
Ranging Limits:	250 yards to 1500 yards
Ranging Velocities:	30 feet per second to 1500 feet per second
Minimum Ranging Acceleration:	3000 feet per second
Wing Span Setting Limits:	15 feet to 100 feet
Required Voltages:	Sight & Selsyn power 115 v. 400 cycles Desiccator motor 208 v. 400 cycles Computer Potentiometer 27.5 v. DC (Filtered) Computer In-Out Lamp 27.5 v. DC
Telescope Field:	75 degrees
Magnification:	Unity
Desiccator Pump Capacity:	475 cubic feet per minute

separately on airplane adjacent to the sight. It dries and circulates the air from the dome and sight chambers. Static desiccators dehumidify the sealed optical compartments of the sight.

2. THEORY OF OPERATION

The Hemisphere (Nose) Sighting Station

The hemisphere sighting station is a stationary sighting instrument used by the nose gunner to track a target and to remotely-control the nose-gun turret. The sight optical system directs light rays from any chosen point in a hemispheric field into the eye of the operator. A Selsyn system, composed of azimuth and elevation Selsyns, transmits azimuth and elevation sight position information to the computer and to the gun turret. A gyro is used for lead prediction. A ranging device determines range, converts it to a voltage signal and transmits it to the system computer to aid in the calculation of gun correction angles.

The Optical System

The main optical system of the hemisphere sight images a target in the focal plane of the eyepiece. Auxiliary optical systems superimpose on the target image additional images such as a reticle, a range scale, a target size scale, a ranging ring and a computer "in-out" signal light. An auxiliary camera system deviates a portion of the light ray from the combined optical systems and directs them to the camera lens for recording purposes. A luminous ring, the diameter of which may be varied by the operator, is provided in the sight field for ranging purposes.

The Selsyn System

The azimuth and elevation Selsyn generators, located on the hemisphere sighting station, send signals corresponding to the sight position to the Selsyn differential generators, located in the computer. The sight position signal is modified at the computer by the addition of corrections, when necessary, and the resultant signal is sent to the control transformers in the gun turret.

The Free Gyro System

The gyro is used to indicate to the computer the angle traversed by the target during the prediction-computing time interval. Specifically, the gyro is used in the computing circuit to predict the lead correction necessary for advancing the guns ahead of the target. The gyro does this by very accurately measuring the angle traversed by the target during the prediction-computing time interval. The free gyroscope is so named because it is free to move in any direction within approximately 15 degrees of the gyroscope axis. Movement of the control grips positions the gyro unit so that the motor shaft is parallel to the line of sight as long as the gyro is caged. When the firing trigger on the sighting station is pressed, a solenoid in the gyro is energized and the caging cone is drawn away from the gyro motor frame, thus freeing the gyro. The housing will continue to be moved by the sight gearing, but the axis of the motor shaft and gyro flywheel will remain fixed in the same direction as it was at the instant it was uncaged.

The Camera

The camera is used to make a permanent record of combat action. When the firing trigger on the sighting station is pressed, the camera action starts. The camera records images of the target, the ranging ring, the reticle and the range-and-target scale readings. An overrun control continues the camera action for a limited period after the gunner has released his firing trigger.

The Ranging System

The ranging mechanism of the hemisphere sight determines the range of the target and transmits it electrically to the system computer. The mechanism is controlled manually by the ranging lever on the operator's right control grip.

The Desiccator System

With the exception of the gyro and Selsyn assembly section, the eyepiece lens cell, and the control-grip assembly section, the chambers of the sights are either statically or dynamically desiccated.

The eyepiece chamber and the objective-lens-cell assembly are hermetically sealed units. These chambers have charging and evacuating valves through which the air can be evacuated and the chamber charged with an inert gas such as nitrogen. The eyepiece lens cell, a completely sealed unit, is seal-mounted over the rear opening of the eyepiece chambers and is not desiccated.

The circulatory system dries and pumps air through the chambers of the sight not desiccated by other means. A pump forces air through desiccant-containing jars, through aluminum pipes to the dome space, outer space of the periscope tube, range compartment and back to the pump. This cycle is continued as long as the pump is turned on.

SECTION VII—MODELS "J" AND "K" RETIFLECTOR SIGHTS

1. INTRODUCTION

This section contains descriptive data, for the models "J" and "K" retiflector sights, designed and manufactured by the General Electric Company. (See Table I, Figure 2-79.)

The instructions contained in the section form a part of the complete instructions issued for the operation and service and the overhaul of the B-36 remote-control turret system.

General Description

The models "J" and "K" retiflector sights are standard equipment on the pedestal and the yoke sighting stations, respectively, which are used in the B-26 remote-control turret system. The two sight models are functionally the same; however, their main component parts are different and are not interchangeable. The model "J" retiflector sight has its reflector plate, filters, and ring-and-bead sight so arranged that its line of sight is parallel to the body of the sight; the model "K" has these component parts so arranged that its line of sight is at right angles to the body of the sight.

The model "J" retiflector sight is mounted on the sight yoke which is located in the center of the upper portion of the elevation assembly on the pedestal sighting station. The model "K" retiflector sight is mounted on the front, or closed end, of the yoke on the yoke sighting station.

Each sight model supplies a DC range input signal to the computer, through a range po-

Figure 2–79. Table 1—Sights and Their Location.

tentiometer. A reticle assembly, which is contained in the lamp housing of the sight, is used to establish the range of the target. The range potentiometer is co-ordinated with the reticle assembly so that as the range of the target varies, as indicated by the reticle image which is projected upon the reflector plate, the input signal from the sight to the computer is varied to correct for the change in range.

Detailed Description

Optical System. (Figure 2-80). The optical system produces the reticle image through the following components: the double-filament reticle lamp (8), the light source for the image; the condensing lens (10), which gathers and projects the light through the optical system; the orange-colored filter (11), which gives the reticle image its color; the reticle assembly, consisting of the range reticle (13), neutral reticle (14), and target-size reticle (15), each of which contains slots to break down the light from the reticle lamp (8) into a circular pattern of dots to form the reticle image; the 45-degree first-surface mirror (17), which reflects the reticle image upward through the cover glass (18) onto the Mangin mirror (2); the Mangin mirror, which

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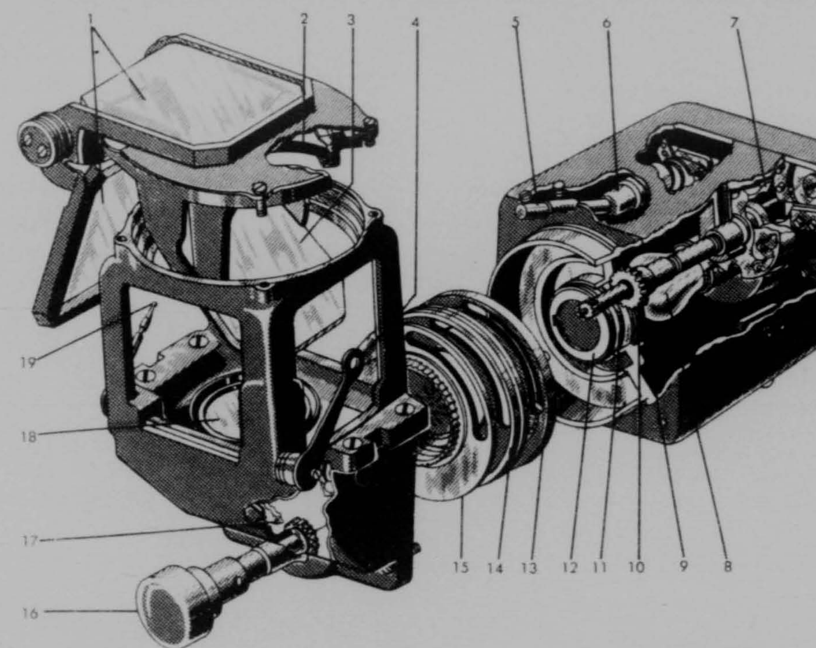


1. SKY FILTERS
2. MANGIN MIRROR
3. REFLECTOR PLATE
4. RING
5. COMPUTER INDICATING LIGHT ROD
6. COMPUTER INDICATING LIGHT
7. RANGE POTENTIOMETER
8. RETICLE LAMP
9. RANGE INPUT GEAR
10. CONDENSING LENS
11. FILTER
12. INDICATOR RETICLE
13. RANGE RETICLE
14. NEUTRAL RETICLE
15. TARGET-SIZE RETICLE
16. TARGET-SIZE INPUT KNOB
17. 45-DEGREE MIRROR
18. COVER GLASS
19. BEAD

Figure 2–80. Partially Exploded View of Retiflector Sight.

collimates the light rays that form the reticle image and reflects them onto the reflector plate (3); and the reflector plate, on which the reticle image is projected and through which the gunner sights his target.

Sky Filters. Hinged sky filters (1), (Figure 2-80) are provided to reduce the glare from brilliant sunlight and to increase the brightness of the reticle image. In night operation, the filters can be swung up, out of line of the sight.

Ring-and-bead (Peep) Sight. If the optical system should fail to work, the ring-and-bead sight (4 and 19), (Figure 2-80) can be moved into place for emergency sighting.

Electrical Elements. A potentiometer (7), controlled by the movements of the range-reticle assembly (13), provides the computer with an electrical signal which represents the range of the target. The reticle lamp (8) is built with two independent filaments to insure a replacement if the one in use should burn out. A filament-selector switch, for use of either filament, is located on the outside of the removable cover at the rear of the lamp housing. The intensity of the light from the filament lamp can be varied by turning the reticle-lamp rheostat on the sighting station.

2. OPERATION

Principles of Operation

Optical System. (Figure 2-81). The light from the reticle lamp passes through the or-

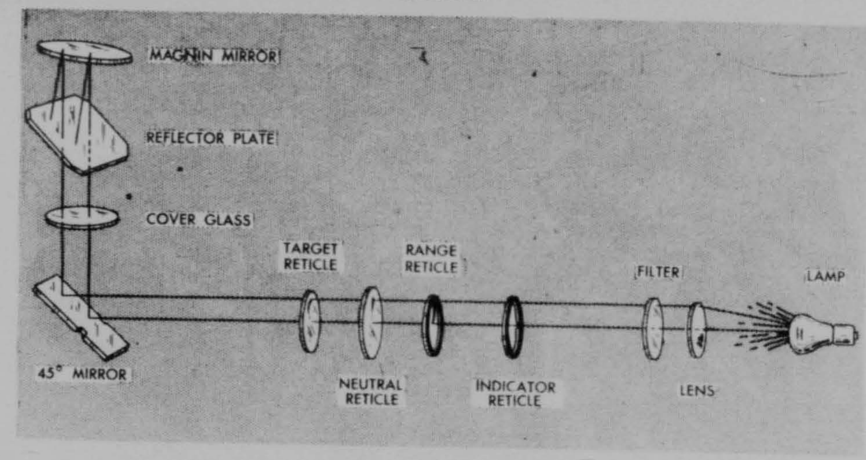
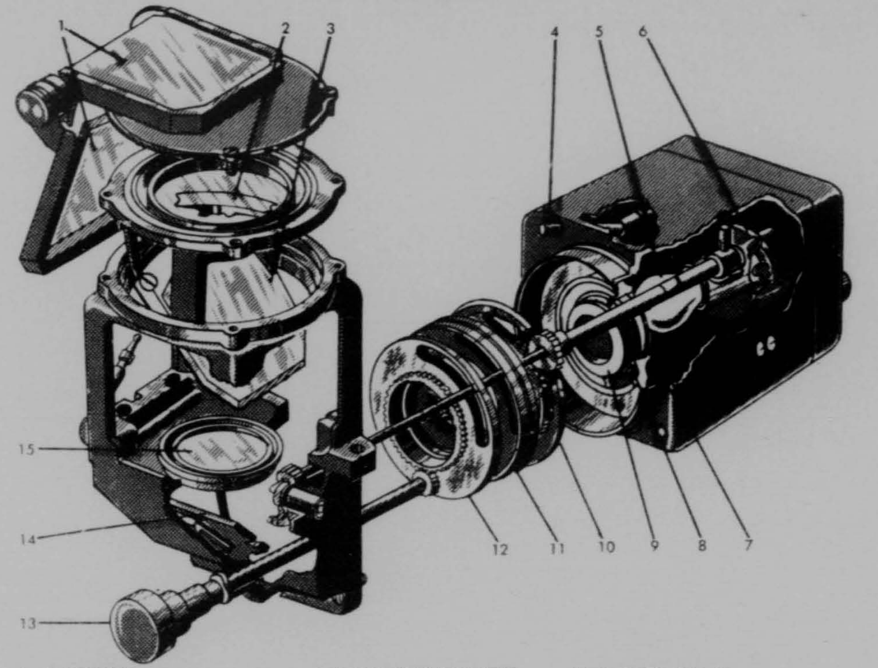


Figure 2–81. Schematic Diagram of Optical System of Retiflector Sight.

ange-colored filter, the condensing lens, and an indicator disc (mask) that has a circular opening the size of the maximum reticle image. The indicator disk contains an opening, cut into the inside diameter, which permits passage of light through the target-size and the range numerals. The light continues through the reticle assembly where it is broken up in dots which form the reticle image. In addition, the target-size and range numerals (illuminated index mark) are formed. The formed reticle image is reflected upward by the 45-degree mirror through the cover glass to the reflector plate. At this point, approximately 95 per cent of the light passes through the plate to the Mangin mirror. This mirror is so shaped and located, with respect to the reticle assembly, that the light rays from the reticle mirror are collimated, or made parallel, and reflected back to the reflector plate. Approximately 80 per cent of the remaining light is passed through the reflector plate, and the balance, 20 per cent, is reflected toward the eye of the gunner. These light rays form an image of the reticle at an infinite distance (infinity). Any object in line with the center of this reticle image will appear in the same position, irrespective of the distance of the gunner's eye from the reflector plate. A slight movement of the gunner's eye, up or down or from side to side, will not change the relative position of the target and the reticle image.

Reticle Assembly. (Figure 2-82). The target-size reticle (12) is located nearest to the body assembly; the neutral reticle (11) is in the middle; and the range reticle (10) is between the neutral reticle and the indicator reticle (9). The neutral reticle is connected to the other two reticles by a differential pinion gear. Thus, when either of the outside reticles is moved, the neutral reticle is moved proportionately. The three reticles ride on the inner surface, or circular bore, of the housing. When either of the outer reticles is turned, the teeth on the inside surface of the reticle flange turns the neutral pinion; the pinion, in turn, rotates the neutral reticle. The relationship of the slots of the range, neutral, and target-size reticles to each other determine the diameter of the image. The range of target-size adjustment is from 15 to 75 feet. The range scale indicates range in yards from "250" to "1500." The apertures of the target-size reticle and the range reticle are similar but curve in opposite directions. The apertures of the neutral reticle are radial and straight. Each of the three reticles contains a central hole to permit the passage of light to form the center dot of the reticle image when the angular relationship of the three reticles with respect to each other is changed. The gunner determines the



1. SKY FILTERS
2. MANGIN MIRROR
3. REFLECTOR PLATE
4. COMPUTER INDICATOR LIGHT ROD
5. RETICLE LAMP
6. RANGE POTENTIOMETER
7. CONDENSING LENS
8. FILTER
9. INDICATOR RETICLE
10. RANGE RETICLE
11. NEUTRAL RETICLE
12. TARGET-SIZE RETICLE
13. TARGET-SIZE INPUT KNOB
14. 45-DEGREE MIRROR
15. COVER GLASS

Figure 2–82. Partially Exploded View of Retiflector Sight Showing the Range and the Target-Size Input Gear Arrangement.

wing span of the target and varies the position of the target-reticle assembly by turning the target-size input knob (Figure 2-83). In normal operation the gunner sets the target size just before aiming at a target and allows the target reticle to remain in position. The gunner varies the size of the reticle image by changing the position of the range-reticle assembly (Figure 2-84). This is accomplished by turning the range-input grip on the sighting station. When the range-input gearing (Figure 2-82) turns the range reticle, it also turns the slider of the potentiometer which, in turn, sends the range correction to the computer. There are eighteen dots forming the reticle image at close range (largest circle), twelve dots at approximately eight-hundred yards range (medium circle), and six dots at approximately fifteen-hundred yards range (small circle).

The light from the lamp (4) (Figure 2-85) passes first through the indicator reticle (a disc whose inner diameter is slightly larger than the maximum reticle-image diameter), then the portion which comes through the center opening falls upon the range reticle (3). At this point, all light is blocked except that passing through the curved slots, the center dot, and the range and the target-size numerals. At the neutral reticle (2), the curved segments of light cross the straight reticle slot. Where they cross, light is permitted to pass through. This step forms dots of light. However, more dots are formed than are wanted; thus, as these dots fall on the target reticle (1), only those which intersect a slot in the

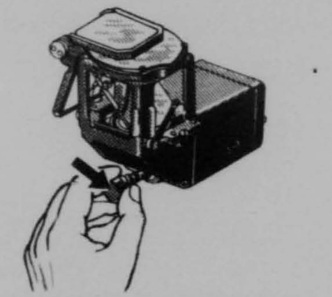
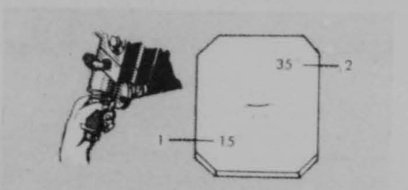


Figure 2–83. Target-Size Input Knob.



1. RANGE IN HUNDREDS OF YARDS
2. TARGET SIZE MEASURED IN FEET

Figure 2–84. Reticle Image Adjusted to Span Target at 1500 Yard Range.

target reticle get through to the first-surface mirror. In this way, the proper dots to form the reticle image are selected. Changing the position of any reticle changes the relationship of the slots and thus changes the selection of reticle-image dots. (Figure 2-82)

The two rectangular-shaped openings in the indicator reticle permit passage of light for the target-size and the range indications. The narrow slot above this opening passes light which becomes the index mark on the reflector plate. The wide, curved openings in the range and neutral reticles pass the light for the target-size reticle. Those for range are on the range reticle.

Use With Computer

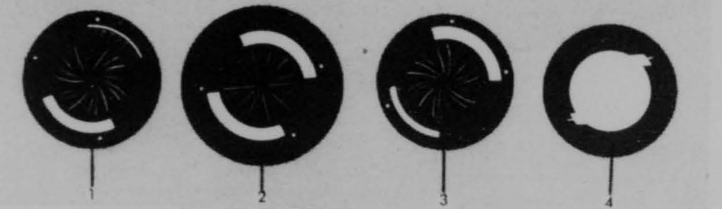
When the system uses the computer, two adjustments must be made by the gunner:

Upon finding the target and identifying it, the gunner estimates, or knows, its wing span or length. If, for example, a target with a sixty-foot wing span is sighted, the gunner turns the target-size input knob, which is located on the left-hand side of the upper sight and in front of the gunner on the pedestal sight, until the figure "60" appears on the reflector plate. With the setting made, the gunner aims the sight, bringing the center dot of the reticle image to bear on the target.

The gunner adjusts the diameter of the reticle image (by turning the range grip or range wheel) so that the circle of dots just spans the target.

Use Without Computer

A small indicating lamp (6) (Figure 2-80) in the sight is turned on when the system is in operation without a computer. A small part of this light is passed through a glass rod (5) which projects into the lower right-hand corner of the first-surface-mirror housing. The gunner should adjust the reticle-image size to the intensity of light considered most suitable. The gunner must now make his own ballistic, parallax, and prediction corrections.



1. TARGET-SIZE RETICLE
2. NEUTRAL RETICLE
3. RANGE RETICLE
4. INDICATOR RETICLE

Figure 2–85. Individual Reticle.

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SECTION VIII—THYRATRON, CONTROL PANELS, JUNCTION BOXES, AND INDUCTION MOTOR

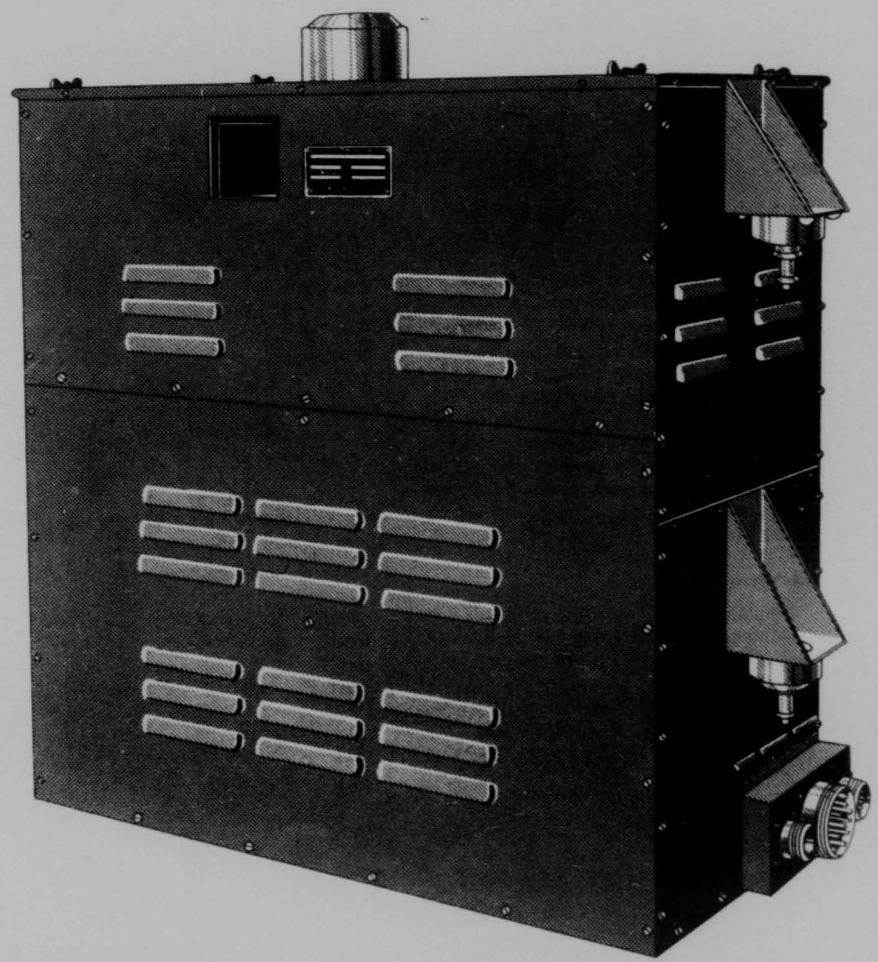

Figure 2–86. Overall View of Thyratron Controller.

1. INTRODUCTION TO THYRATRON

The thyratron controller (Figure 2-86), General Electric assemblies No. 8678508G1 and 8678508G2, is airborne equipment first designed for the remote-control turret system 2CFR87A1 installed in the B-36 airplane. Assembly No. 8678508G1 is used in the upper, lower, and nose systems and assembly No. 8678508G2 is used in the tail system. The thyratron controller is an electronic device which receives AC error signals from the Selsyn control transformers in the turrets and amplifies and converts these signals to DC power for driving the turret motors. It also supplies 27-volt DC auxiliary power for each system. One controller is required for each turret-and-sight combination in the B-36 turret system.

Data pertinent to the thyratron controller may be found in the following publication:

AN 11-70AA-31 Operations and Service Instructions for the Model 2CFR87A1 Remote-Control Turret System.

2. DESCRIPTION OF THYRATRON

This section contains general information pertaining to the thyratron controller and covers, in detail, the description of the various components thereof.

Test Equipment Required

The test equipment listed in Figure 2-87 is required to adjust, align, check and repair the thyratron controller.

Detailed Description

Eight thyratron controllers are used in the B-36 remote-control turret system, one for each turret. Input power to each thyratron controller is three-phase system is wye connected. Selsyn signals created by movement of the sights are fed into the controller and are then amplified and used as signals to the power thyratron tubes. The thyratron controller contains a frame, tube shelf, cover, base plate, and six panel assemblies.

Interchangeability

There are two types of thyratron controllers used on the B-36 remote-control turret system, assembly No. 8678508G1 which is used for the upper, lower and nose systems and assembly No. 8678508G2 which is used for the tail system. The amplifier panel contains different feedback resistors in the circuits for the one-horsepower motors in the upper, lower, and nose systems than the amplifier panels used in the circuits for the one-half-horsepower motors in the tail system.

3. OPERATION OF THYRATRON

Note: Before referring to this section it is important that the reader have a thorough

Fig. & Item No.	Quantity per Equip.	Name of Unit	Army Type Designation	Required Characteristics
2-1	1	Analyzer-Electric, Weston Model 772, with case, or Simpson Model 260		For testing thyratron controller circuits
2-2	1	Voltohmmeter Type 165 (Junior Volt-ohmyst)	7800-973900	For testing thyratron controller circuits
2-3	1	V. T. Voltmeter, Hewlitt-Packard Model 400A	7800-973830	For testing thyratron controller circuits
2-4	1	Oscillograph Cathode Ray Dumont Type 208	7800-610000	For testing thyratron controller circuits
2-5	1	*Thyratron tube tester	9167198G1	Testing thyratron tubes in thyratron controller
2-6	1	Commercial tube tester		Testing standard tubes
2-7	1	Indicator phase rotation	Local mfg	Checking phase rotation
2-8	As required	Wrench-strap	8003-44A17113	For tightening AN connectors

The equipment marked with an asterisk (*) is furnished by the manufacturer.

Figure 2–87. Table 2-2—Equipment.

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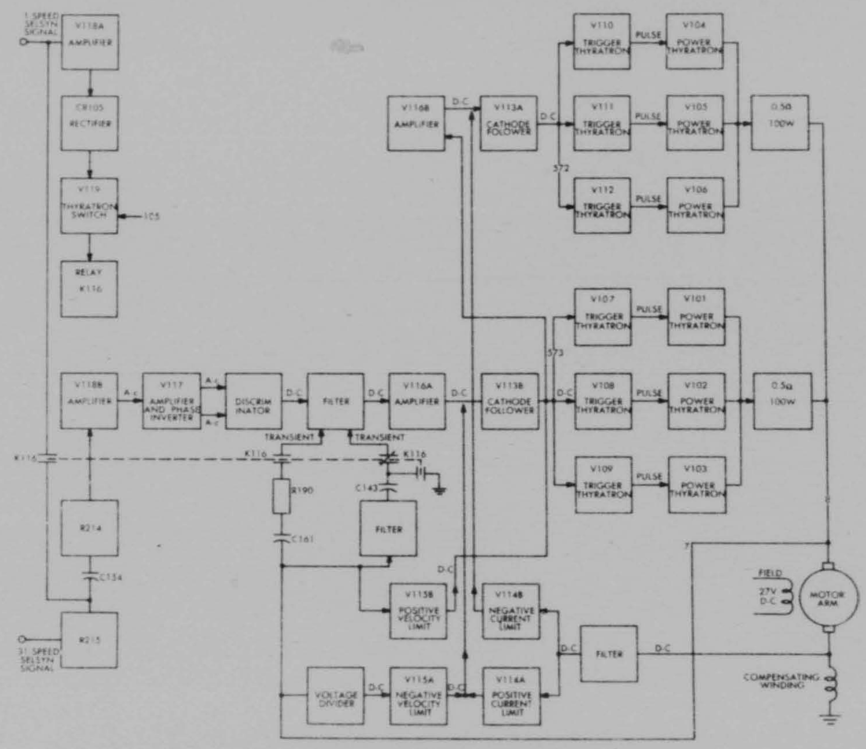

Figure 2—88. Block Diagram of Thyratron Controls.

understanding of section IV, Theory of Operation in AN-11-70AA-31 (B-36 Operation and Service Handbook).

The thyratron controller is a device for supplying DC power to the turret motors so that they will drive the turret in such a manner as to always point in the same direction as the sight (computer is not operating in the circuit). This DC power is obtained by thyratron rectification of the AC power supplied to the thyratron controller. The DC voltage output can be varied by proper control of the grids of the thyratrons. The method of control is such that the DC voltage output is proportional to the error signal or voltage output of the Selsyn control transformers. Since the speed of a DC motor with constant applied field is directly proportional to the voltage applied, this means that the speed of the motors is proportional to the error signal.

The operation of the system can be stated as follows: (Figure 2-88). Assume that the sighting station and turret are aligned and are stationary. Moving the sight will cause error voltages to appear at the output of the Selsyn control transformers located in the turret. These voltages are fed into the thyratron controller. When the sighting station and turret are within 3 degrees of alignment, the 31-speed Selsyn signal is effective; otherwise, the 1-speed signal is effective. This signal is first amplified, converted into two voltages 180 degrees out of phase in the phase inverter, and then fed into the discriminator. The discriminator output is a DC voltage whose amplitude is directly proportional to the AC output voltage and whose polarity is determined by the relative phase of the AC input voltage.

This DC voltage is then filtered. In the filter section, a feed back voltage, which is a function of the rate of change of turret-motor armature voltage, is introduced. The connections of the feed-back depend on whether the 31- or 1-speed Selsyn signal is effective. The feed-back signal is used to keep the system from oscillating.

After being amplified in V116, the DC voltage is fed to twin-triode V113. The outputs of the cathode follower are used to control the trigger thyratrons. With zero Selsyn signal, the outputs of the cathode follower are both minus seven volts DC. With a Selsyn signal, the output of one of the cathode followers will go negative (with respect to minus seven volts) while the other one will go positive. The output that goes positive will cause the bank of trigger thyratrons (to which it is connected) to conduct. The output of the pulse transformers in the plate circuits of the trigger thyratrons will then be positive pulses which will cause one bank of power thyratrons to conduct. When the power thyratrons conduct, a voltage will be applied to the turret motor armature. One bank of power thyratrons (V101, V102, V103) have their plates connected to the AC lines. This bank, when conducting, delivers a positive voltage to the turret motor. The other bank has the cathodes connected to the AC line and therefore delivers a negative voltage. The direction in which the motor rotates depends on the polarity of the output voltage.

In order to explain how the thyratrons can deliver a variable DC voltage some explanation of how a thyratron works must be given. Thyratrons are gas-filled triodes or tetrodes. The grid can control the start of conduction, but it cannot stop conduction. The only way to stop conduction is to let the plate voltage become zero or negative or to make the plate current zero. When an AC voltage is applied to the plate the tube can conduct only during the positive half-cycle. Therefore, when the grid is made sufficiently positive during the positive half-cycle of the plate voltage the tube will start conducting and will conduct until the plate voltage becomes zero. By varying the point during the cycle at which the tube begins to conduct, the portion of the cycle during which the tube conducts can be controlled. The greater the portion of the cycle during which the tube conducts, the greater will be the DC voltage output. (Figure 2-89).

Current limiter V114 is used to limit the current passing through the motor armature to 60 amperes in the case of the one horsepower motors and 35 amperes for the one-half horsepower motors. Both of these currents are five times the normal rating of the motors.

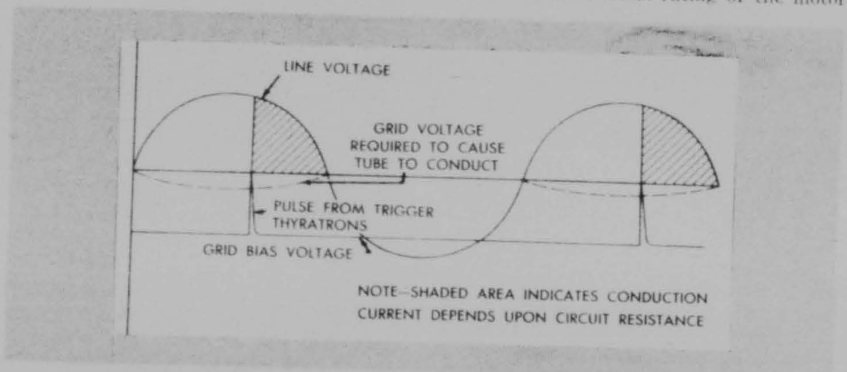

Figure 2—89. Schematic Drawing of Thyratron Controller Characteristics.

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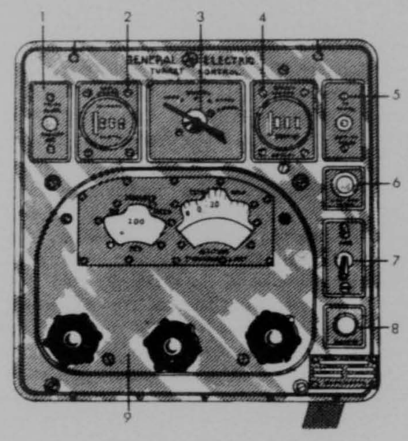
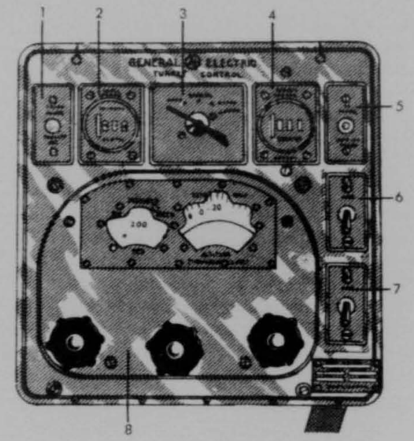


1. CIRCUIT BREAKER
2. LH ROUNDS COUNTER
3. "STAND BY" SWITCH
4. RH ROUND COUNTER
5. CIRCUIT BREAKER
6. INDICATOR LIGHT
7. SAFETY SWITCH
8. INDICATOR LIGHT
9. ALTITUDE AND HANDSET AIRSPEED

Figure 2–90. Upper and Lower Turret Control Panel.



1. CIRCUIT BREAKER
2. LH ROUNDS COUNTER
3. "STAND BY" SWITCH
4. RH ROUNDS COUNTER
5. CIRCUIT BREAKER
6. SAFETY SWITCH
7. CAMERA SWITCH
8. ALTITUDE AND AIRSPEED HANDSET

Figure 2–91. Tail Turret Control Panel.

Since torque is directly proportional to current, this limit is really a torque limit circuit.

Voltage limiter V115 limits the voltage and hence, the speed of the motor. This is done to protect both the motor and the controller.

4. CONTROL PANELS

There are eight control panels (Figures 2-90 and 2-91); one each for the upper-forward, upper-aft, and lower-aft turrets; one for the nose; and one for the tail. Because of the similarity in operations to be performed, several duplicate or similar devices are used in the eight control panels such as uniswitches, circuit breakers, handsets, and rounds counters. In addition, the tail control panel has a camera switch (Figure 2-91), on-the-target interlock relay, and radar and radar-computer position on the uniswitch (3), while the upper-forward, upper-aft and lower-aft turrets control panels have turret position indicating lights and "stand-by" and "door open" positions on the uniswitch. Each panel is connected to other parts of the system by a standard AN connector.

Location

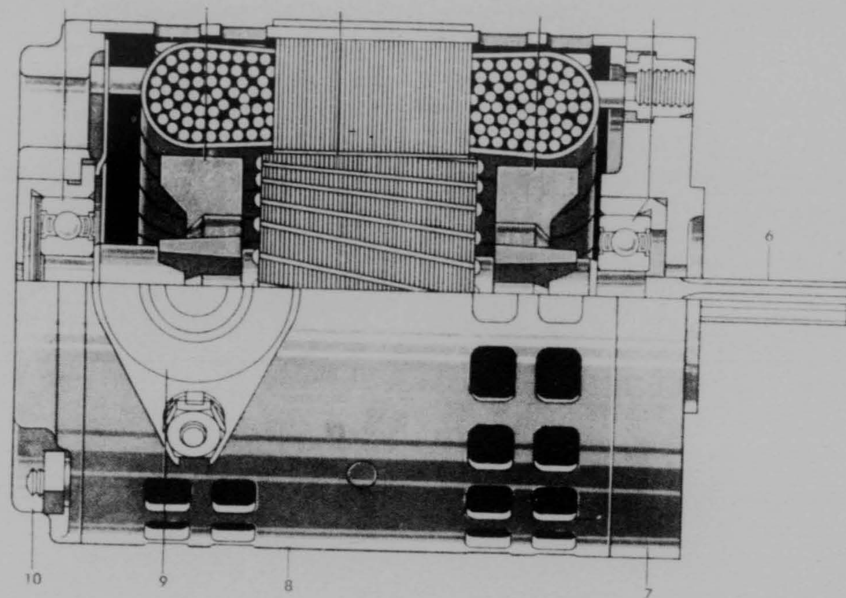
The panels are conviently located so that each gunner can quickly and easily control and operate the equipment at his command. The control panels are mounted on bulkheads near each turret system's sight.

5. JUNCTION BOX

To eliminate long cable runs with their weight and voltage drop, system units are connected to a junction box located near the individual turret. Eight junction boxes are used in the remote control turret system; one for each turret. Junction boxes for the eight turrets are identical in size and method of mounting.

Location

All system junction boxes are located in close proximity to each turret's thyratron controller and computer. The nose-system junction box is located directly forward of the nose-turret computer on airplane station 89.



1. BEARING
2. FAN
3. ROTOR
4. FAN
5. BEARING
6. SHAFT
7. PINION-END SHIELD
8. STATOR
9. CONDUIT ADAPTER
10. END SHIELD

Figure 2–92. Cutaway View of Motor Model 5K25DJ19.

The upper-left and upper-right forward-system junction boxes are mounted directly aft of airplane station 283 above their respective turret computers. The lower-left aft-system junction box and the lower-right aft-system junction box are located aft of airplane station 1184, forward of the turrets. The upper-right aft-system junction box and the upper-left aft-system junction box are mounted above each turret's thyratron controller aft of airplane station 1184. The tail system junction box is located in the tail section of the airplane, aft of airplane station 1306 in the pressurized compartment.

Cables, jointed to the unit by means of standard AN connectors, serve as links between the junction box and its associated units. The turret connects to the junction box by means of three cables; the turret door mechanism by one cable; and the turret retraction mechanism by two cables. The computer, thyratron controller, and control panel lead into one cable which, in turn, leads into the junction box.

6. AC INDUCTION MOTORS

The turret motors consist of a stator, rotor, and end shields. Models 5K40BJ22, 5K40BJ29, 5K40JJ20, and 5K40JJ33 each are equipped with magnetic brakes and an overload switch. Models 5K25DJL9 and 5K25DJ20 are not so equipped. Ratings for the motors are given in table

The following description is applicable to all motor models except where differences are specifically mentioned. (Figures 2-92, 2-93, 2-94.)

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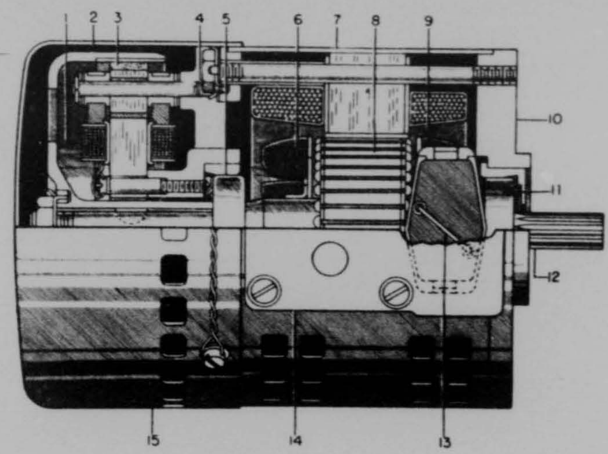


1. Brake-coil assembly
2. Drum-and-sleeve assembly
3. Brake shoe assembly
4. End shield
5. Bearing
6. Fan
7. Stator
8. Rotor
9. Fan
10. Pinion-end end shield
11. Bearing
12. Shaft
13. Overload switch
14. Terminal box
15. Cover

Figure 2–93. Cutaway View of Motor Model 5K40BJ22.

Stator Assembly

The stator is a machined steel shell into which a stack of slotted punchings is pressed. A four-pole, three-phase, wye-connected winding is wound in the slots. All models, except models 5K25DJ19 and 5K25DJ20, have a thermal overload switch imbedded in and tied to the stator winding.

Note: Model 5K25DJ20 is a six-pole machine.

Operation of AC Induction Motor

The induction motor makes use of a constantly revolving magnetic field in the stator to turn the rotor. The copper bars of the rotor are cut by the revolving magnetic field. A starting torque in the motor is produced by the revolving field which cuts across the copper bars and generates an EMF in the closed circuit of the rotor. Since the EMF is induced in a closed circuit, current will flow in the rotor bars. The frequency of the EMF generated in the rotor at standstill is the same as the frequency of the applied voltage to the stator.

Starting Torque. The current in the rotor conductors at standstill is expressed by the ratio of the rotor voltage at standstill to the rotor impedance at standstill. The rotor impedance at standstill limits the current to about five times the full-load value. This large starting current produces a high starting torque.

Slip. When the motor is not carrying any load, the rotor will revolve at practically the speed of the revolving field, that is, at synchronous speed. It cannot turn at speed greater than that of the revolving field. When the motor is loaded, the rotor slows down, and as a result, it "slips" through the constantly revolving magnetic field of the stator. Slowing down results in the cutting of more lines of force, and the generating of more EMF. The resulting increased current will produce more torque. The rotor will continue to slow down until sufficient torque is produced to overcome the retarding torque of the load. The ratio of the difference between the synchronous rpm minus the motor rpm to the synchronous rpm times 100 is called the "per cent slip." If its value at full load is about four per cent, the revolving magnetic field will make one revolution while the rotor will make 0.96 revolution.

Load Characteristics. When the rotor is at standstill, the rotor frequency is the same as the line frequency. At full load, the rotor frequency is equal to per cent of slip times the line frequency. As the load on the motor increases, the motor slows down and slips more rapidly through the revolving field, causing the rotor current and the frequency of the

1. BRAKE-COIL ASSEMBLY
2. DRUM-AND-SLEEVE ASSEMBLY
3. BRAKE SHOE ASSEMBLY
4. END SHIELD
5. BEARING
6. FAN
7. STATOR
8. ROTOR
9. FAN
10. PINION-END END SHIELD
11. BEARING
12. SHAFT
13. OVERLOAD SWITCH
14. CONNECTOR
15. COVER

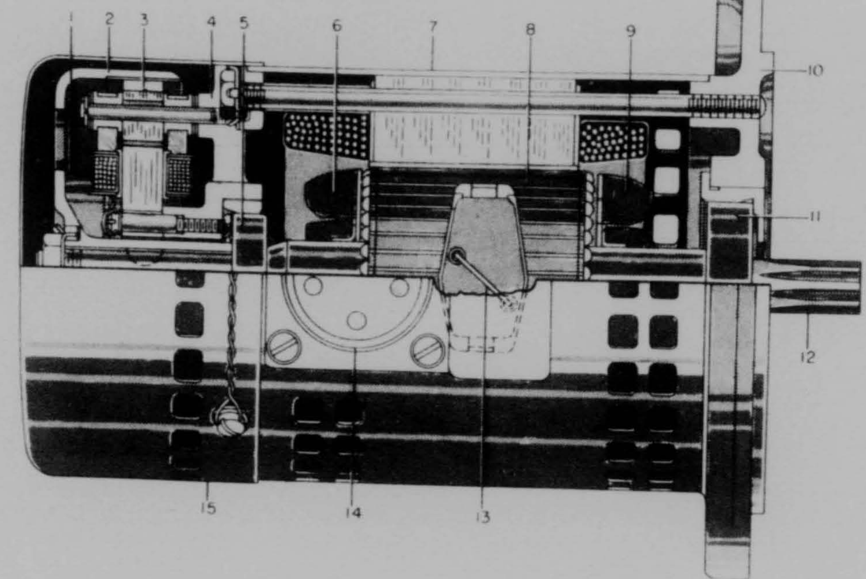


Figure 2–94. Cutaway View of Motor Model 5K40JJ20.

rotor current to increase. The characteristics of an induction motor is such that up to a certain point, called the "breakdown point," or "point of maximum torque," the greater the rotor current, the greater the torque. Beyond this point, the torque decreases as the rotor current increases. The relation between speed, torque and current is shown in Figure 2-95.

Direction of Rotation. A reversal in rotor rotation may be accomplished by changing the relative sequence of magnetic flow cutting the rotor. This can be accomplished by interchanging the connections of any two of the three leads of a three-phase induction motor.

Motor Brakes. Magnetic brakes are used in some types of fractional-horsepower induction rotors to aid in bringing the rotor to a quick stop after the energizing current to the

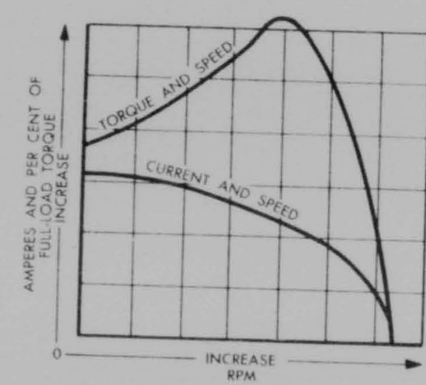


Figure 2–95. Curves Showing Relationship of Speed, Current, and Torque in an Induction Motor.

stator has been cut off. The brake consists essentially of a brake drum mounted on the shaft extension. The brake drum fits over the brake-coil assembly. Brake shoes are held against the inner side of the drum by spring pressure. The brake-coil assembly is connected in parallel with the field windings. When current is supplied to the field, the brake shoes pull away from the drum. Rotation is free until current is cut off. Upon cutoff of the current, the brake-coil assembly becomes de-energized and spring pressure pushes the brake shoe against the drum, bringing the rotor to a quick stop.

Overload Protector. Overload thermal protectors are used on some motors to prevent the motor from overheating when a greater load than normal is applied. The overload protector consists of a thermally controlled switch connected in series with the coil of the power contactor in a junction box. When the switch opens, the contactor is de-energized, thereby opening contacts in each of three lines to the motor. This protector is so adjusted that if the motor current becomes higher than normal, a movable diaphragm opens a pair of contacts and cuts off the power. Upon cooling of the motor, the contacts close and power can again be applied.

SECTION IX—FREE GYRO AND COMPUTER

1. FREE GYRO

General Description

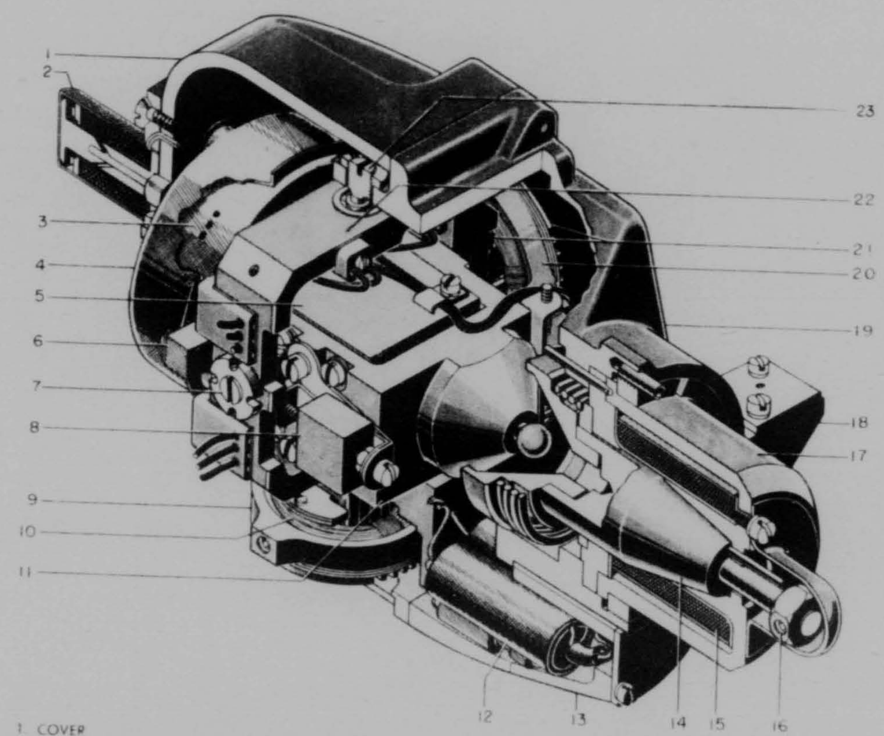
Each sighting station has one fully gimbaled gyroscope mounted so that it moves, in azimuth and elevation, with the line of sight. A gyroscope, located in the tail of the B-36 airplane, is provided for the AN APG-3 antenna.

The different gyroscopes which are covered by this Handbook are located as shown in table 2-1.

Function. The gyro is used in the computing circuit to predict the lead correction necessary for advancing the guns ahead of the target by an amount proportional to the range and relative speeds of the bomber aircraft and the target. The gyro does this by very accurately measuring the angle traversed by the target during the prediction-computing-time interval. The free gyroscope is so named because it is free to move in any direction within approximately 15 degrees from the caged position of the gyroscope axis.

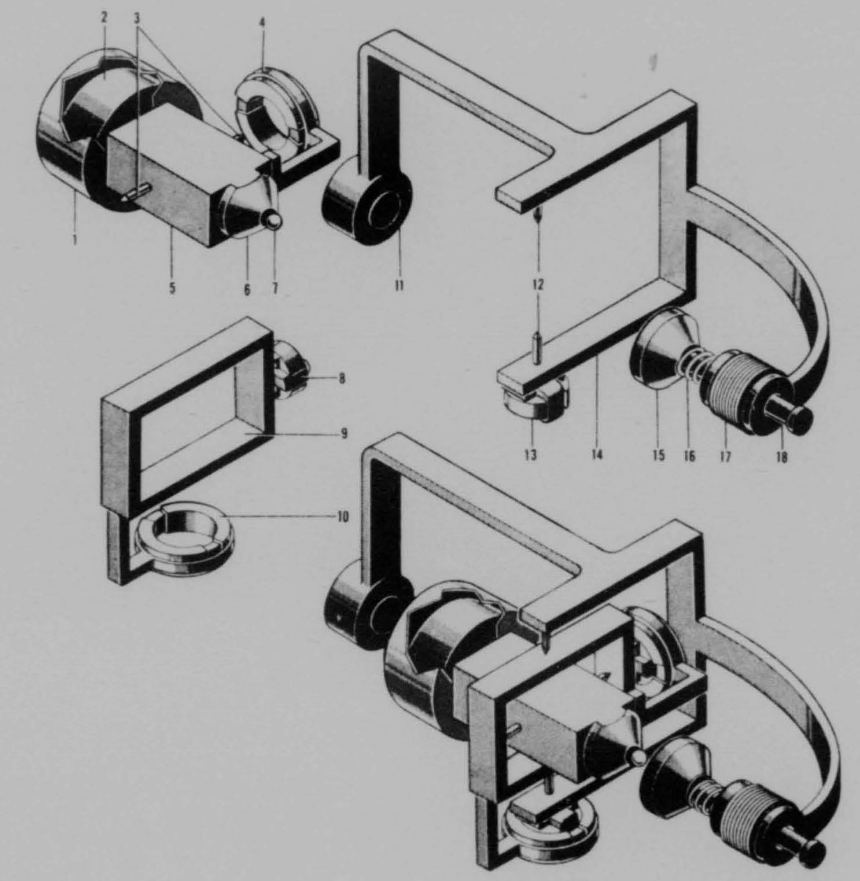
The gyroscope assembly (Figure 2-96) consists of the following basic component assemblies; the motor and flywheel assembly (5); the gimbal system which consists of three parts: the bracket and pin assembly (11), the gimbal ring (22), and the housing (19), the solenoid assembly (15); the holding solenoid assembly (2); and the azimuth (10) and elevation (21) Selsyns. The other component assemblies consist of the cover (1) and the noise suppressors (12). A junction box, which houses the capacitors and resistors, and other electric equipment is a part of the gyroscope electric system. The junction box is mounted on the sighting station, except in the case of the gyro for the radar installation where the junction box is mounted on the gyroscope cover.

Motor and Flywheel Assembly. The gyroscopic action is provided by a flywheel (5) (Figure 2-96) mounted on the shaft of a small DC motor. The motor is rated 27.5 volts, 10,000 (plus or minus 25 per cent) revolutions per minute. The motor has a permanent-magnet field and a conventional armature which rotates in ball bearings. Since the performance of this type of gyro is not dependent upon accurately held speed, no form of speed control is provided. The motor and flywheel assembly (5) is mounted within a bracket and pin assembly, (11). The flywheel of the motor is enclosed by a cover (4) which is attached to one end of the bracket and pin assembly. The flywheel cover has a spherical surface against which the holding solenoid applies its breaking force when the solenoid is energized. The caging end of the bracket and pin assembly has a conical projection in which there is a ball-tipped caging pin. The motor



1. COVER
2. HOLDING SOLENOID ASSEMBLY
3. FLYWHEEL
4. FLYWHEEL COVER
5. MOTOR AND FLYWHEEL ASSEMBLY
6. FLYWHEEL COVER MOUNTING BRACKET
7. BEARING PIN
8. BALANCE WEIGHT
9. STATOR MOUNTING BRACKET (AZIMUTH)
10. SELSYN ASSEMBLY (AZIMUTH)
11. BRACKET AND PIN ASSEMBLY
12. NOISE SUPPRESSORS
13. LEAD CASE
14. PLUNGER AND PIN ASSEMBLY
15. SOLENOID COIL ASSEMBLY (UNCAGING)
16. STOP NUT
17. SOLENOID COIL CASE
18. LEAD CASE
19. HOUSING
20. STATOR MOUNTING BRACKET (ELEVATION)
21. SELSYN ASSEMBLY (ELEVATION)
22. GIMBAL RING
23. BEARING PIN

Figure 2–96. Cutaway View of Free Gyro.



1. FLYWHEEL COVER
2. FLYWHEEL
3. ELEVATION BEARING AXIS
4. ELEVATION SELSYN STATOR
5. MOTOR AND BRACKET ASSEMBLY
6. CONICAL PROJECTION OF BRACKET
7. BALL-TIPPED CAGING PIN
8. ELEVATION SELSYN ROTOR
9. GIMBAL RING
10. AZIMUTH SELSYN STATOR
11. HOLDING SOLENOID
12. AZIMUTH BEARING AXIS
13. AZIMUTH SELSYN ROTOR
14. HOUSING (SERVES AS OUTER GIMBAL)
15. NON-MAGNETIC CAGING CONE
16. CAGING SPRING
17. SOLENOID COIL ASSEMBLY
18. PLUNGER

Figure 2-97. Schematic Diagram of Gyro and Gimbal System.

and bracket assembly is supported in the gimbal ring (22) by two bearing pins (7). Two adjustable counterweights for balancing the assembly are mounted on opposite sides of the bracket. The leads from the motor and Selsyn stator are brought to a clamp on top of the motor. Flexible leads connect from the motor clamp to an adjacent clamp on the gimbal ring.

Gimbal System

The gimbal system (Figure 2-97), in which the motor and flywheel assembly is supported to permit its movement in any direction, consists, essentially, of the bracket and pin assembly (11) (Figure 2-96), the gimbal ring (22) and the housing (19). The bracket and pin assembly which is fixed to the motor and flywheel assembly, is provided with a set of two ball bearings and two thrust-bearing disks seated in the sides of the bracket on its horizontal axis. The bracket-bearing axis is perpendicular to the gyro motor-shaft axis. The gimbal ring is provided with one set of two ball-pointed bearing pins along its horizontal axis, and one set of two ball bearings and two thrust-bearing disks along its vertical axis. The bracket and pin assembly is supported on its horizontal axis in the gimbal ring by the two ball-pointed bearing pins which engage the ball bearings and bearing discs seated in the bracket. This set of bearings on the horizontal axis permits the gyro motor-shaft axis to remain in the same space direction in which it was pointed, before the gyro was uncaged, as the housing is turned in elevation. The gimbal ring in turn, is supported on its vertical axis in the housing by two ball-pointed bearing pins which engage the ball bearings and bearing disks seated in the ring. This set of bearings on the vertical axis permits the gyro motor-shaft axis to remain in the same space direction in which it was pointed, before the gyro was uncaged, as the housing is turned in azimuth. The gimbal system does not permit free movement of the gyro through 360 degrees, but it does permit free movement through approximately 15 degrees in any direction from the caged position, which is ample latitude for computing the lead-prediction-correction angle.

The position of the motor and flywheel assembly within the housing is electrically transmitted to the computer in the remote-control turret system by means of the elevation and azimuth Selsyns. The rotor (8) (Figure 2-97) of the elevation Selsyn assembly is mounted on the gimbal ring, and the stator (4) is mounted on the bracket and pin assembly. The rotor (13) of the azimuth Selsyn assembly is mounted in the gyroscope housing, and the stator (10) is mounted on the gimbal ring.

Selsyns

The azimuth and elevation (lateral and vertical) deflection Selsyns are variable-voltage transformers in which the secondary stator voltage is a function of the relative positions of the stator and primary rotor voltage. The stator coil assembly consists of a toroidal (doughnut-shaped) winding on a build-up of magnetic ring laminations, which provide a low reluctance flux path for the stator flux. The coil is mounted in an aluminum case which protects the coil from mechanical damage and provides a means of mounting the stator. The rotor consists of a random-wound coil on a laminated magnetic core. The flux spreader furnishes an additional magnetic path and also provides a means of mounting the rotor.

Caging Mechanism

The gyro is spring-caged and electrically uncaged by means of a solenoid-controlled armature or plunger (18) (Figure 2-97). When the caging solenoid is energized, it pulls the magnetic plunger in, compressing the spring (16). This pulls the nonmagnetic caging cone (15) away from the ball-tipped caging pin (7). The motor shaft may then move approximately 15 degrees in any direction with respect to the housing before the caging pin hits the cone. When the solenoid coil is de-energized, the spring forces the caging cone over the caging pin, bringing the motor shaft into alignment with the plunger. At the end of the caging stroke the ball is held within a hollow cylinder at the apex of the cone. Thus, regardless of the displacement which occurs while the gyro is uncaged, the spring and cone bring it back to within a small fraction of a mil of the same position when it is recaged. The entire caging mechanism, except for the ball-tipped caging pin on the motor bracket, is a separate assembly held in place on the housing by an annular nut. The outside of the cylindrical coil case serves as the main support for the gyro in its mounting on the sight.

Housing. The aluminum housing (19) (Figure 2-96) serves as a part of the gimbal system, and as part of the enclosure of the gyroscope assembly which includes the motor and flywheel assembly, the gimbal system, the caging mechanism, and the noise suppressors. The caging mechanism is located in the end of the housing, and the noise suppressors are located in the housing, under the caging mechanism.

Cover. The cover (1) (Figure 2-96), which completes the enclosure of the gyroscope assembly, is of molded plastic compound. The outside surface and the mounting face is zinc-sprayed to a depth of approximately 0.015 inch; this acts as an electrical shield for radio noise that results from motor commutation. The cover contains an air filter which provides for ventilation of the gyroscope assembly. The holding solenoid assembly is mounted on the cover.

Holding Solenoid

The holding solenoid assembly (2) (Figure 2-96) is mounted on the cover along the normal gyroscope motor-shaft axis. Thus the solenoid plunger acts radially on the braking sphere of the flywheel cover when the motor and flywheel assembly is in any position within its range of movement.

Junction Box

The junction box is connected to the gyro by a flexible cable. It houses the capacitors and resistors used to adjust the phase angle and magnitude of the Selsyn stator voltages. Also located in the junction box is the additional DC line filtering, necessary to lower the gyro-conducted and radiated noise to within specifications. The gyro junction box serves as a connection for the camera mounted on the yoke and pedestal sighting stations. The camera is controlled by a switch on the box.

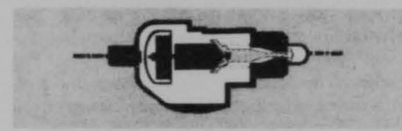


Figure 2–98. Gyro Caged.

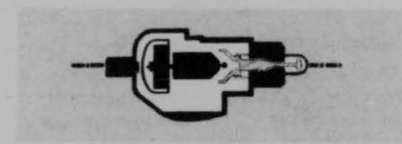


Figure 2–99. Gyro Uncaged.

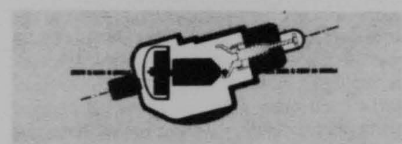


Figure 2–100. Gyro Caged and Against Stop.

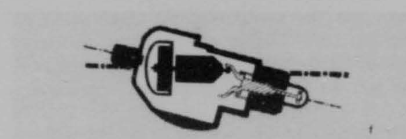


Figure 2–101. Gyro Uncaged and Against Stop.

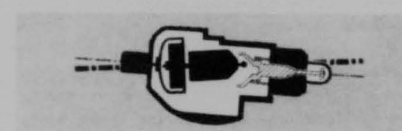


Figure 2–102. Gyro Uncaged and Locked.

Noise Suppressors. This information will be furnished as a revision at a later date.

Operation

The gyro is used to indicate to each computer the angle traversed by the target during the prediction-computing-time interval. The motor of the gyro is a 27-volt, DC type and is energized when the uniswitch located in the control panel is thrown to the "standby" position. The gyro remains energized when the uniswitch is in either the "door open" or the "operation" position.

Principles of Operation

The gyro is normally caged (Figure 2-98), and in this position its motor-shaft axis is parallel to the line of sight. The caging mechanism end points toward the target. As the sight or the radar antenna moves, the entire gyro moves with it so that the motor shaft always points along the line of sight. When the trigger is pressed, a solenoid in the gyro is energized and the caging cone is drawn away from the motor frame (Figure 2-99). The housing will continue to move with the sight or antenna but the motor shaft will stay pointing in the same direction it did at the instant it was uncaged (Figures 2-100 and 2-101).

As the housing turns, the relative position of one or both of the Selsyn rotors and stators is similarly changed and voltages are generated in the stator windings. These voltages energize the computer-output-unit motors by way of the gyro amplifier, and cause them to turn the computer's total-correction-unit Selsyns through the same lateral and vertical angles as the sighting station. The output unit motors are capable of making corrections much faster than the gyro housing moves in tracking a target. Consequently, the total-correction-unit Selsyns quickly catch up with the gyro Selsyn angles, reduce the net signal voltage to the drop-out point of the gyro-amplifier relays, and stop the computer-output-unit motors. As soon as the sight or antenna, which contains the housing, has again moved enough to provide the computer's gyro amplifier with a pick-up signal, the output-unit motors again run. The movement of the output units is, therefore, a series of rapidly repeated small steps following very closely the angular movement of the sight. At all times the lateral and vertical corrections are within a few mils of the displacement of the gyro Selsyns.

When the time interval of prediction computation has expired (one time-of-flight multiplied by the attack-factor correction), a relay operates in the computer. This relay energizes the holding solenoid in the gyro which locks the gyro in its subtended position (Figure 2-102), and starts the following chain of events: The output units are brought into agreement with the computed corrections; the gyro is unlocked and recaged; the timer unit in the computer is reset and the computation is started again after a predetermined time delay of 0.065 second. However, the output units or computer corrections remain in their previous position until the new time-of-flight problem has expired. At this time the out-put units are again allowed to drive into agreement with the newly computed gyro correction. This process is repeated as long as the trigger is depressed. (Reference should be made to the theory of operation for the computer in AN 11-70AA-54.)

When the trigger is released, the caging solenoid is reset and the caging cone realigns the gyro-motor shaft with the line of sight. At the same time, the power supply to the computer-output-unit motors is re-established and the prediction corrections in the computer are quickly brought back to zero.

When the trigger is pressed for a new attack problem, the entire cycle of prediction is repeated.

2. COMPUTER

The eight turret-sight systems of the B-36 airplane each are equipped with one computer. Each computer has been adjusted for the parallax between its sight and turret. Aside from the parallax adjustment, all computers are the same, except the nose turret-sight system computer, model 2CH2C1-N, which is equipped with a different timer-unit motor and a different total-correction unit assembly. This difference in the nose turret-sight system computer computes a faster lead-prediction correction cycle which is necessary to combat the faster moving attacks encountered in the nose hemisphere. Additional nomenclature is suffixed to the computer model-number designation, which is stamped on the computer nameplate, to identify that computer with the turret-sight system with which it belongs.

Each computer weighs approximately 100 pounds, and the four shock mounts together weigh one pound.

Description

Purpose of Computer. For short ranges, with a stationary gun and a stationary target, a gun can be aimed directly at the target by sighting along the gun barrel. However, in aerial combat this ideal condition is seldom met, and the direction of the gun's bore axis must be shifted with respect to the direction of the target. The amount that the gun must be shifted depends upon the forces acting upon the projectile after it leaves the muzzle of the gun, such as windage and gravity, and upon the movement of the target while the projectile is traveling toward it. If the sight of the radar antenna is not mounted on the gun, but is located at a distance from it, as is the case with the B-36 remote-control turret system, the gun's position must be further changed to compensate for this "parallax" distance.

There are two methods used at present for aiming the guns at the target, namely: noncomputing and computing systems. In the B-36 system, the computer can be switched "in" or "out" of the circuit instantly at the option of the gunner.

Noncomputing Systems. In a noncomputing system, the line of sight is maintained parallel with the gun's axis and the gunner advances the line of sight from the target position by an amount determined by him from his own experience and judgment.

Computing System. In a computing system, such as the remote-control turret system used on B-36 airplanes, the sight or the antenna is held on the target by the gunner, and the relative position of the guns is determined by a computer mechanism. The use of the computer eliminates the guesswork on the part of the gunner in estimating range, ballistic, parallax, and lead-prediction corrections and leaves him free to concentrate on accurately tracking the target and keeping the sight aligned with it.

When a noncomputing system is used, the same corrections must be taken into account in order that the projectile will strike the target.

Computer Corrections

All computer corrections can be classified into three groups, namely: ballistics, parallax, and lead prediction. These three corrections are added together and are electrically introduced into the remote-control turret system as a single total correction.

Ballistics. The ballistics correction compensates for the windage and gravity forces that cause a projectile to deviate from a straight line after leaving the muzzle of the gun.

Parallax. The parallax correction compensates for the distance along the longitudinal axis of the airplane between the turret and the sight that is controlling the turret.

Lead Prediction. The prediction correction compensates for the distance the target travels from the time the projectile leaves the gun until it strikes the target.

Basic Operation

The computer is essentially a mechanical computing device which receives all its input data in the form of electrical quantities. These input data, then are converted into mechanical shaft rotations for the mechanical portion of the computer. The output of the computing mechanism is a mechanical motion which is converted again into electrical quantities for introduction as corrections into the signal circuit between each sight and the turret it controls.

Design Characteristics—Correction Input Limits. The altitude-and-air speed handset and the range potentiometer at the sighting station are designed for computer inputs as follows:

Altitude: 0 to 45,000 feet

Air Temperature: −75° C (−103° F) to +50° C (122° F)

Indicated airspeed: 90 to 275 mph

Range: 250 to 1500 yards

Operating Limits. The computer is designed to operate continuously in any internal ambient rising temperature from 6.7° C (20° F) to +38° C (100° F), or falling temperature from +38° C (100° F) to 17.7° C (0° F), at any altitude between sea level and 40,000 feet. The computer may be operated at higher temperatures for short periods of time.

The computer will operate in any gun azimuth position and between ± 87 degrees gun elevation position.

The maximum correction that can be introduced between sight and gun is approximately 338 mils (19 degrees) in azimuth or elevation.

The 27-volt, DC supply voltage may vary from 26.1 to 28.9 volts; and the 115 volt, 400-cycle supply voltage may vary from 100 to 130 volts.

Limits of Accuracy. At zero degrees gun elevation, all static corrections are within four mils of the nominal value. The elevation correction remains within four mils or less at all gun elevations, but the azimuth correction varies as the reciprocal of the cosine of the gun elevation angle. At ± 60 degrees gun elevation for example, the error in azimuth correction may be ± 8 mils.

Mounting. The computer is mounted on four shock-absorbing brackets to absorb vibration. Internal parts are protected by removable, dust-resisting covers.

Operation

The B-36 remote-control turret system can be operated as a computing system or as a noncomputing system.

Noncomputing Remote Control. In the noncomputing remote-control system, electrical impulses are transmitted between the sight and the turret in such a manner that the turret automatically follows the exact position of the sighting station. Any movement of the sighting station or antenna causes a signal voltage to be applied to the thyratron controller until the turret assumes a corresponding position. The thyratron controller recognizes the polarity of the signal and delivers current in the proper direction to move the guns to the corresponding sight or antenna position.

The guns are, therefore, always in exact alignment with the sighting station, and all corrections must be estimated by the gunner. The sight or antenna must be aimed at the estimated position which the gunner believes, from experience, will cause the projectile to strike the target.

Computing Remote Control

The computing remote-control system is similar to the noncomputing system in all respects, except that a computing mechanism is connected in the electrical signal circuit between the sight and the gun turret. When not in use, this computer has no effect on the signals and the system continues to operate as a noncomputing system. However, when the computer is switched in, the computer automatically makes all computations for ballistics, parallax, and lead prediction; it displaces the distribution and changes the polarity of the signal voltage, as required, between the sighting station and the gun turret. The signal voltage is displaced by the necessary amount to aim the guns so that, when the sight or antenna is aimed directly at the target, the projectile will strike the target.

Computer Corrections. All the corrections can be classified into three groups; namely, ballistic, parallax, and prediction (lead). These corrections are expressed as angles, either in mils or degrees. An angular mil is 1/6400 part of a circle, and is approximately equal to the angle subtended by one yard at a range of one thousand yards. The ballistic, parallax, and prediction corrections are computed separately in the computer, and then added together to get the total correction.

Ballistic Correction. Ballistic correction compensates for the deviation of the projectile from the gun line. This deviation is caused by wind and gravity forces acting upon the projectile. The total ballistic correction consists of windage, gravity, and range corrections.

Affecting Factors. The factors affecting these corrections are air density (altitude, corrected for outside air temperature), true airspeed (indicated airspeed, corrected for altitude and outside air temperature), range, gun elevation, and gun azimuth positions. These factors may be regrouped as follows.

Windage. Windage is the term generally used to designate the effects of altitude, temperature, and airspeed on the path of the projectile (Figure 2-111).

A windage force is caused by the airspeed of the airplane. This windage has nothing to do with the actual wind on the surface of the earth; it is the apparent wind, as seen by the gunner, which is merely the airplane's speed relative to the air. This windage force is applied to the projectile in a direction parallel and opposite to the direction of flight.

In an airplane, the wind is always from the front to the rear, never deviating more than a few degrees from the fore-and-aft axis of the airplane. If the projectile is fired at zero degrees elevation (horizontal) and straight forward or straight aft, it is not deviated from the gun line by the windage force. However, for any other gun position, this force will deviate the projectile from the gun line toward the rear.

The windage deviations are symmetrical about the fore-and-aft center line of the airplane. Maximum deviation occurs when the target is broadside; and, for any given angle from the center line, it is greater in the two forward quadrants, since the energy of the projectile is lost at a faster rate in these quadrants because of greater resultant windage forces. The offsetting correction is always forward in the direction in which the airplane is moving.

The magnitude of the deviation, and hence the correction, depends upon the true airspeed, air density, and range. The windage correction increases with increase in airspeed and range and decreases with increase in altitude (reduced density). For the short ranges involved, the corection is nearly proportional to the range with other conditions constant.

Gravity. The effect of gravity upon the projectile is to cause it to curve toward the earth. (Figure 2-103). The angular drop of the projectile due to gravity is called "vertical gravity deflection." The offsetting gravity correction is greatest at zero degrees elevation of the gun (horizontal) and decreases with an increase in elevation or depression. Gravity acts upon the projectile throughout its time of flight, and the gravity correction varies almost directly as the time of flight of the projectile.

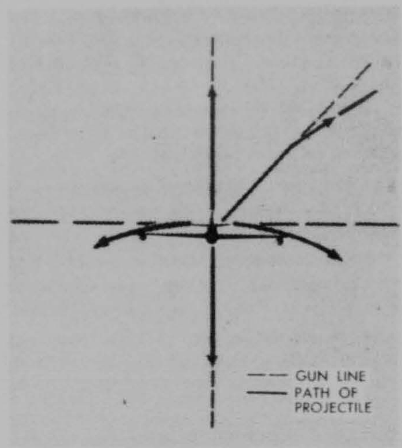


Figure 2—103. Effect of Gravity.

Range is the distance from the gun to the target. As the range is increased, the time of flight of the projectile is increased, which has an effect on all other corrections.

Gravity correction increases with range and is nearly proportional to it for the ranges encountered in computer operation.

Windage correction also increases with range and is nearly proportional to it for the ranges involved in computer operation.

Inputs Required. In order to calculate the ballistic correction, the computer must obtain the following information:

Azimuth and elevation gun position.

True airspeed.

Air density (a function of altitude and outside air temperature).

Range or distance of target from gun.

Parallax Correction. Parallax correction is the angle between the gun and sight (or antenna tracking axis), measured at the target.

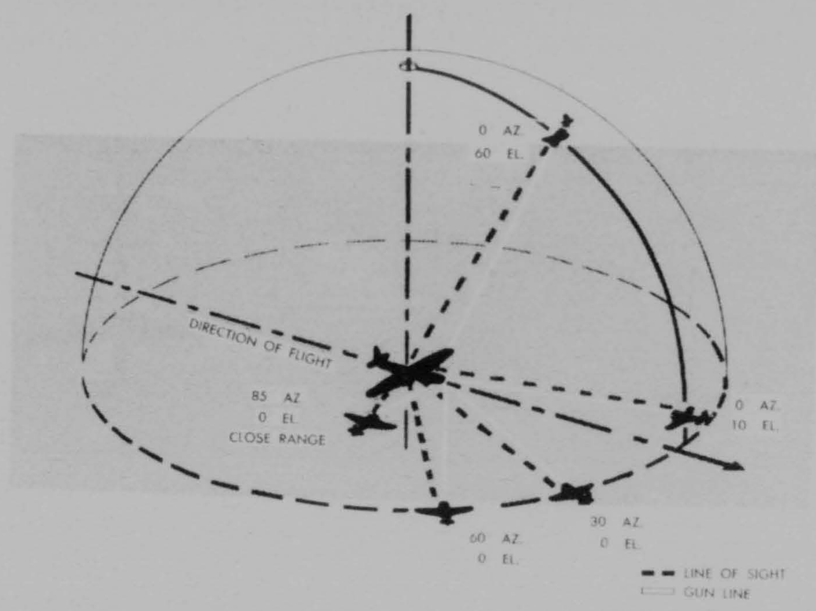


Figure 2—104. Parallax Corrections of Different Angles of Attack.

when the gun and sight are located at different positions on the airplane (Figure 2-104). This figure illustrates the desirability of making the parallax correction, as otherwise the guns would point parallel to the line of sight and would miss the target by the distance between the gun and the sight location. There is zero parallax correction when the gun and the sight are located at the same point. Parallax correction varies for different target positions or range (Figure 2-104). It is zero for straight forward or straight aft positions.

Affecting Factors

The factors affecting parallax correction are elevation and azimuth gun positions, range, and parallax base length (Figure 2-105).

The parallax correction increases from zero degrees to ± 90 degrees elevation and is great at ± 90 degrees.

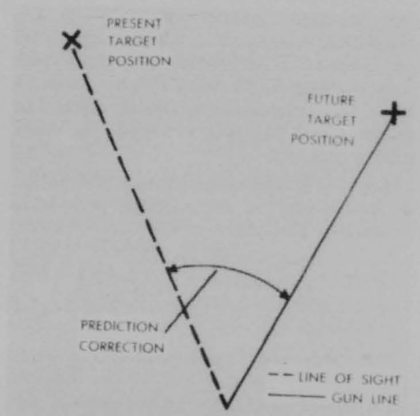


Figure 2—105. Effect of Prediction Correction on Gun Position.

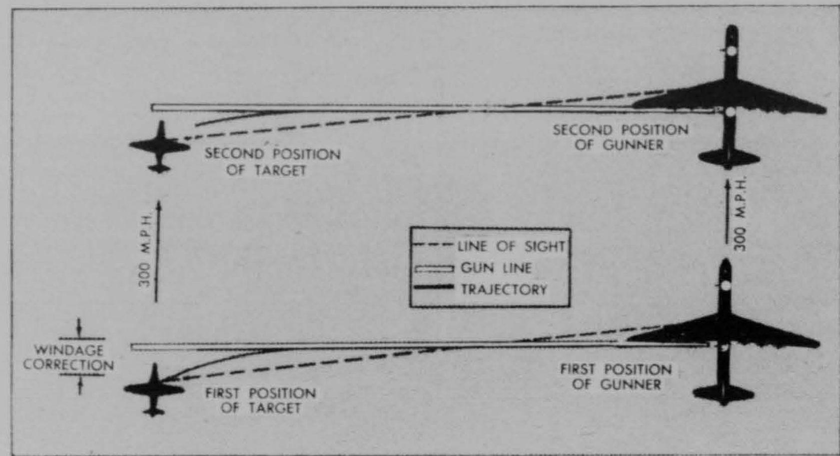


Figure 2–106. No Prediction Correction Required.

The parallax correction increases from zero degrees to 90 or 270 degrees and is greatest at 90 degrees and 270 degrees. The correction again decreases as the gun position moves from 90 or 270 degrees toward zero or 180 degrees azimuth. The parallax correction for a given azimuth position is changed by a change in the gun elevation position.

The parallax correction increases as the range becomes shorter and decreases for longer ranges. When firing at a target 1500 yards distant or farther, the gun line is practically parallel to the line of sight. At short range, the parallax correction increases. The greatest correction is at the minimum range of 250 yards.

Inputs Required. In order to calculate the parallax correction, the computer must have the following information:

Elevation gun position.
Azimuth gun position.
Range or distance of target from gun.
Parallax-base length.

Prediction (Lead) Correction. Prediction correction is an angular correction. It is the angle at the sight between the present and future position of the target (Figure 2-105). This correction is necessary to compensate for the movement of the target while the projectile is traveling from the gun to the target. It is the same correction that a hunter makes when he shoots ahead of a flying bird.

Affecting Factors. Since prediction correction is the angle through which the sight moves in following the target during the time of flight of the projectile (seconds), it is affected by target speed, gun position, windage, and range. To determine the prediction correction it is necessary to predict the future position of the target which is the location of the target at the time the projectile will reach it. The prediction of the future position assumes the path of the target to be essentially a straight line, while the time taken by the projectile to travel to a point on that path is determined from known characteristics of the ammunition. The proper gun orientation is obtained when the target and the projectile reach the same point (future position) at the same time. When the target is traveling in the same direction and at the same speed as the gunner's airplane (Figure 2-106) there is no change in the angle of sight and hence no prediction correction is necessary. Only the ballistic and parallax corrections are required. However, when the target is traveling in the opposite direction (Figure 2-107) there is a very rapid change in the sight angle, requiring a corresponding lead correction angle, or

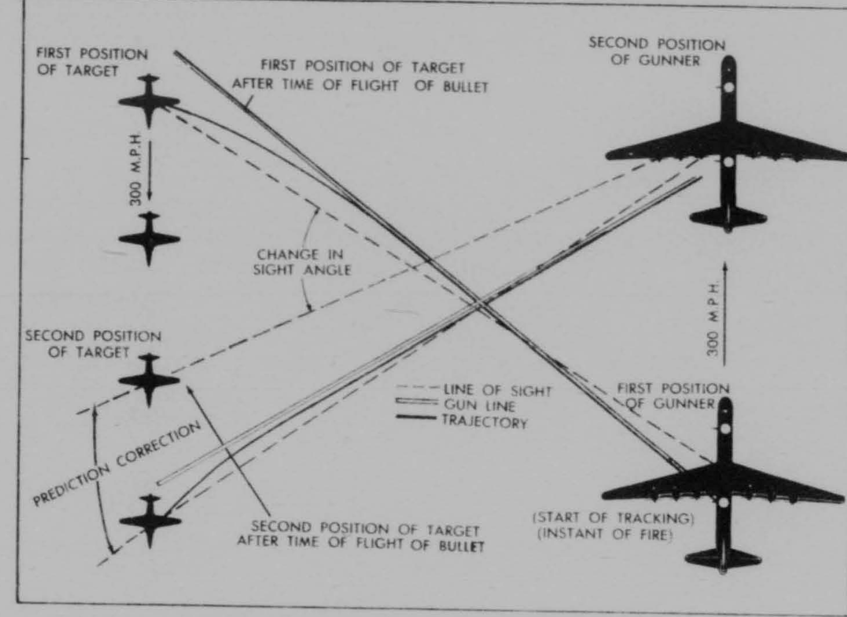


Figure 2–107. Prediction Correction.

"lead prediction." With the proper prediction correction, both the projectile and the target travel to the meeting point during the time of flight of the projectile.

Inputs Required. In order to calculate the prediction correction, the computer must obtain the following information:

Movement of the sight after the trigger is pressed; which requires an indication of the initial sight position, and a measure of its movement away from that position.

A time interval during which the change in sight angle is to be measured. This is a function of time-of-flight and attack factors, which are determined by: characteristics of the ammunition used; range of the target; air density (a function of altitude and temperature); ballistics, as it affects time-of-flight of the projectile; and gun azimuth position.

Totalizing Corrections. All ballistic, parallax, and prediction corrections are added together and appear as a single total correction.

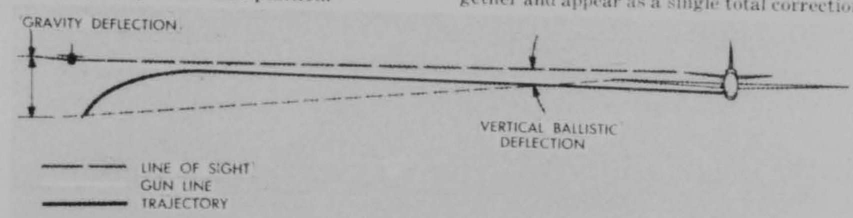


Figure 2–108. Effect of Gravity with No Correction.

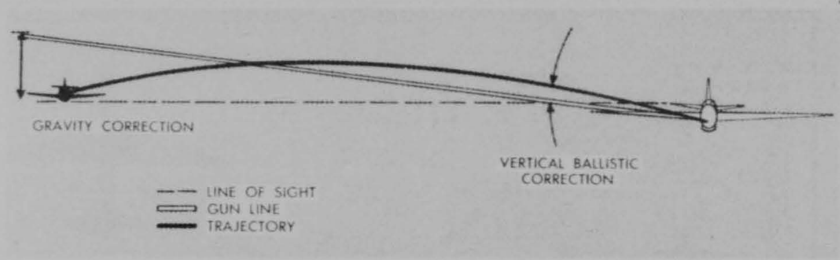


Figure 2–109. Vertical Ballistic Correction Compensates for Gravity Effect.

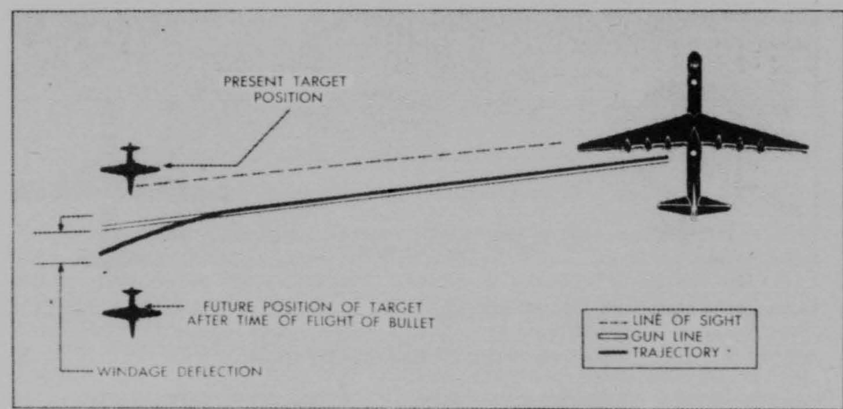


Figure 2–110. Effect of Windage with No Corrections.

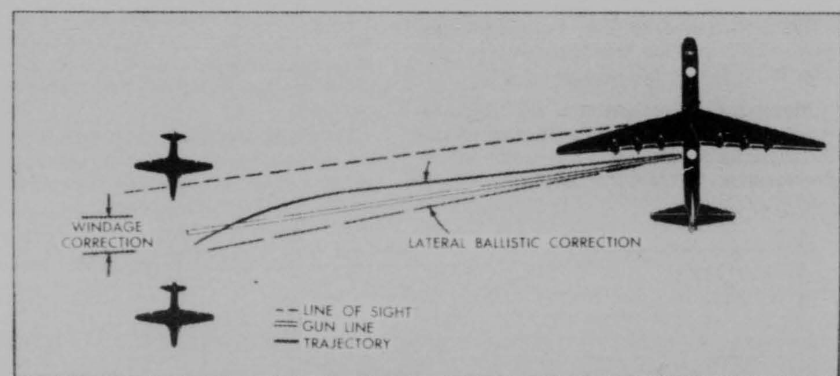


Figure 2–111. Lateral Ballistic Correction Compensates for Windage Effect.

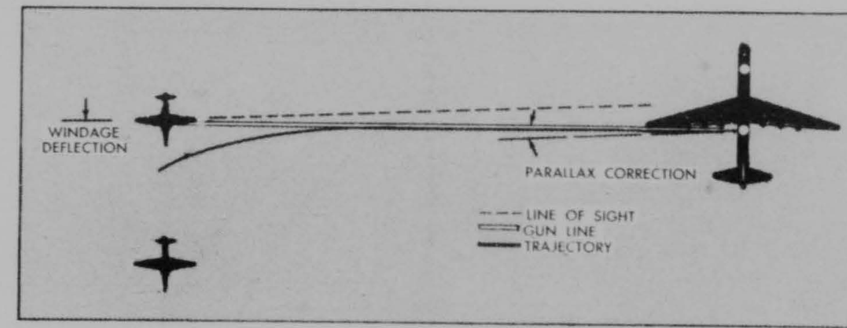


Figure 2–112. Parallax Correction Only.

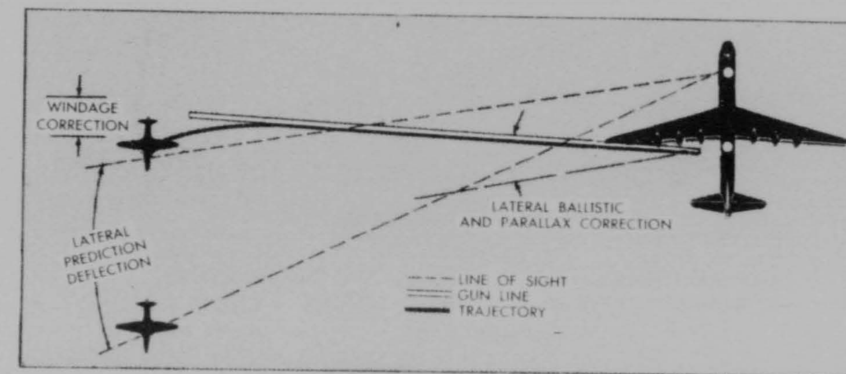


Figure 2–113. Lateral Ballistic and Parallax Correction.

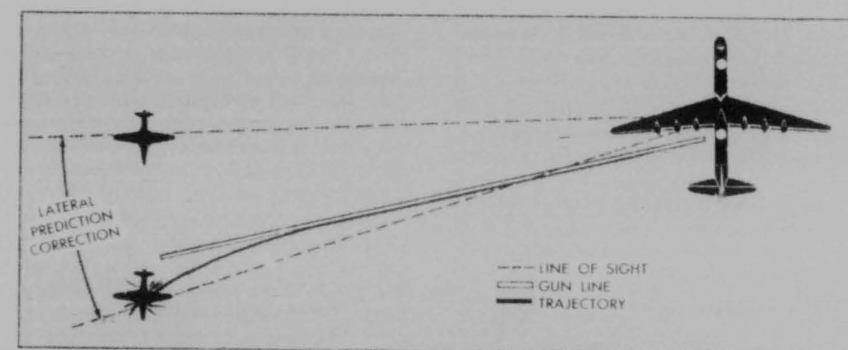
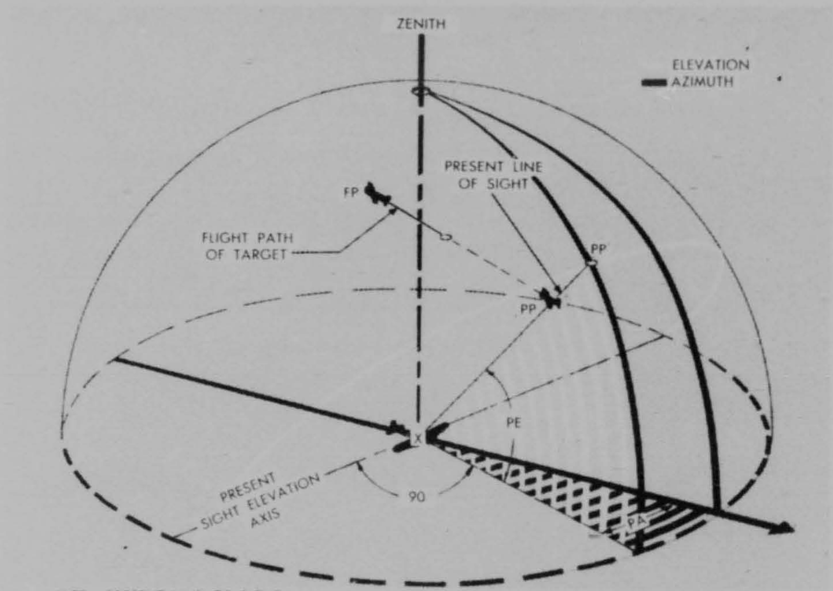


Figure 2–114. Lateral Ballistic, Parallax and Prediction Corrections.



X-PP PRESENT LINE OF SIGHT
X SIGHT POSITION
PP PRESENT POSITION OF TARGET
PP' INTERSECTION OF PRESENT LINE OF SIGHT ON SPHERE

FP FUTURE POSITION OF TARGET
PE ANGLE OF ELEVATION
PA GUN AZIMUTH
NOTE: ○ INDICATES INTERSECTION OF LINE WITH SPHERE

Figure 2-115. Present Target Position.

A deflection of the projectile is caused by gravity (Figure 2-108). The vertical ballistic correction (Figure 2-109) is necessary to correct for this deflection.

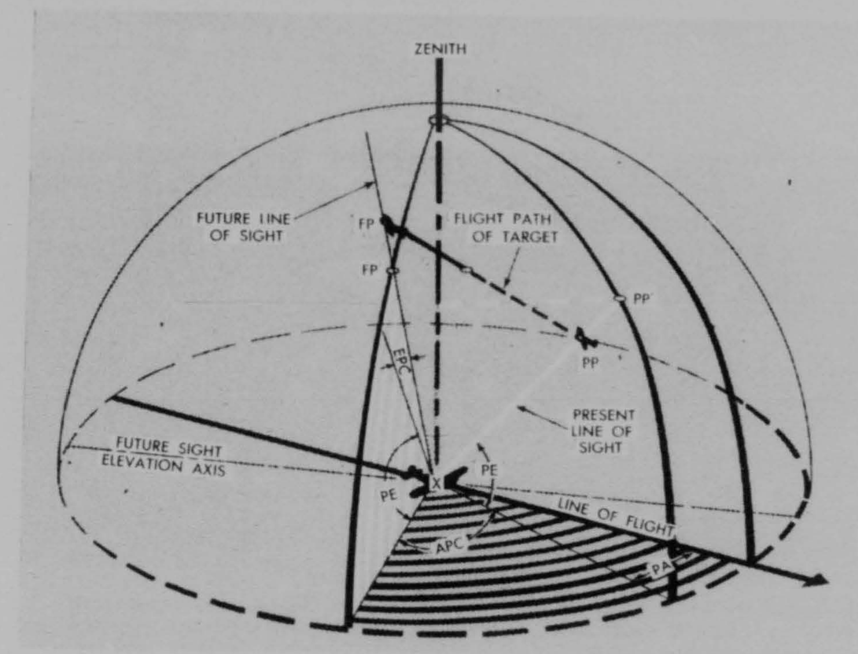
A deflection is caused by windage (Figure 2-114). To offset this it is necessary to introduce a lateral ballistic correction (Figure 2-111).

Parallax correction is also required (Figure 2-112). This is added to the ballistic correction to give the lateral ballistic and parallax correction (Figure 2-113).

The total lateral correction is the sum of the ballistic and parallax corrections and the prediction correction (Figure 2-114).

Corrections During a Burst of Fire. Ballistic and parallax corrections are continuously computed and continuously entered into the remote-control system, while the computer is in operation. However, to prevent setting up large false lead corrections, lead (prediction correction) is computed only when the trigger is pressed (because this is the period when the gunner is likely to be "on target," and tracking smoothly).

Geometry of Lead Computation. When the trigger is pressed to begin a burst of fire, the gun position is corrected only for ballistics and parallax. For the projectiles to hit the target, the prediction correction (lead) must also be computed and added to the other corrections. The prediction correction is computed from the change in target position during a given time interval (which is a function of the time of flight) immediately after the trigger is pressed. The following explanation of lead computation concerns this period from the instant the trigger is pressed until the first correctly aimed projectile is fired.



EPC ELEVATION PREDICTION CORRECTION
APC AZIMUTH PREDICTION CORRECTION

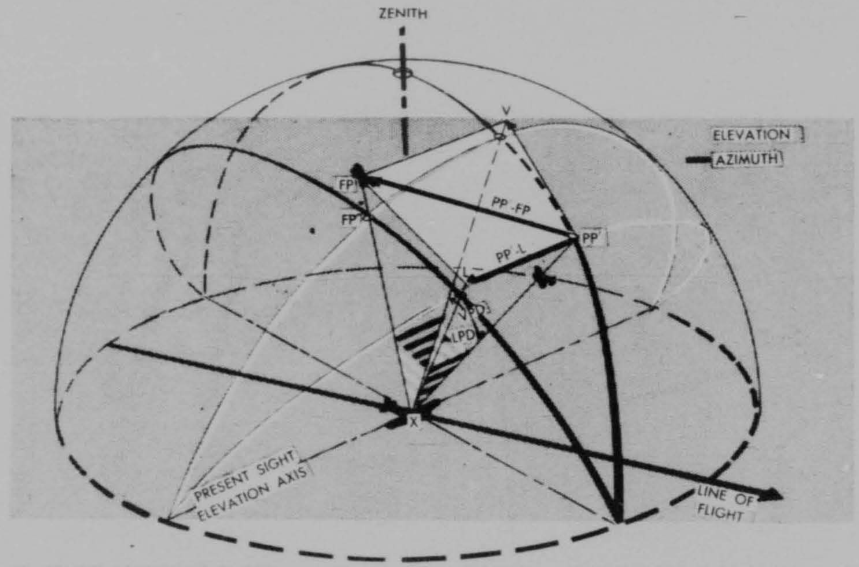
▭ ELEVATION
▬ AZIMUTH

Figure 2-116. Future Target Position.

The position of the target at the instant the trigger is pressed is called the "present" position of the target, and the position of the target when the first correctly aimed projectile is fired is called the "future" position of the target. Accordingly, the lines from the sight to the target at these two positions are called the "present" line of sight and the "future" line of sight. The angle between the present and future lines of sight is called the "total prediction correction," or "lead angle."

The gunner's airplane is shown at the center of a sphere (Figure 2-115), with the line of flight indicated by the arrow. The present position of the target is indicated by the airplane marked PP. Its advanced, or future, position along its flight path is marked FP (Figure 2-116). The radius XPP of this sphere is such that a plane perpendicular to the present line of sight XPP and containing the future target position FP is just tangent to the sphere at point PP (Figures 2-117 and 2-118).

To calculate the correct lead angle, the path of the target relative to the gun must be known during the time of flight of the projectile. Since the path of the target during a given time interval is a straight line, the position of the target can be completely determined by three polar space coordinates, each as a function of time. Since both the gun turrets and sights are mounted to move vertically in elevation and horizontally in azimuth, all corrections must be made in these two directions.



PP—PRESENT POSITION OF TARGET
FP—FUTURE POSITION OF TARGET
PP-FP—TOTAL PREDICTION DEVIATION
PP-V—VERTICAL PREDICTION DEVIATION
PP-L—LATERAL PREDICTION DEVIATION
VPD—VERTICAL PREDICTION DEFLECTION ANGLE
LPD—LATERAL PREDICTION DEFLECTION ANGLE

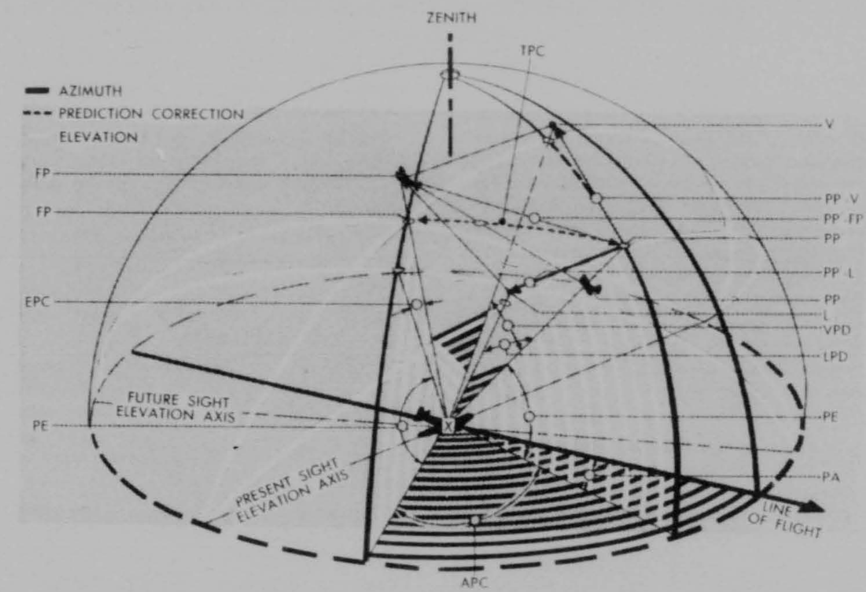
Figure 2—117. Projection of Target Path on Tangent Plane.

The line of flight of the gunner's airplane is considered as zero degrees azimuth and zero degrees elevation, and all target positions are measured from that reference point. The present target position is measured, from zero degrees elevation and zero degrees azimuth, by the number of degrees the sight must be rotated in azimuth, or raised in elevation, to line up with the target.

Two vertical planes through the zenith may be drawn (Figure 2-115), one passing through the line of flight and the other through the present target position. The angle between these two planes is the azimuth position of the target and is denoted by the letters, PA.

The sight elevation axis is perpendicular to the vertical plane through the present target position and the angle of present elevation of the sight about this axis is denoted by the letters PE (Figure 2-115). The elevation angle PE, which brings the sight into alignment with the target, is the elevation sight position. If the guns were fired directly at the present target position (even if the trajectory of the projectiles were a straight line), the projectiles would miss the target since the target would be traveling towards its advanced position FP while the projectiles were traveling from the guns to the present position of the target PP. This makes it necessary to point the guns ahead of the target so that the projectile and target both reach the point FP at the same time. In addition to this, it is necessary to make all ballistic, parallax, and range corrections.

The future position of the target (Figure 2-116) is at an azimuth position PA plus APC and an elevation position PE plus EPC. APC is the change in azimuth position and EPC is the change in elevation position of the sight,



PP-FP—TOTAL DEVIATION
PP-V—VERTICAL PREDICTION DEVIATION
PP-L—LATERAL PREDICTION DEVIATION
VPD—VERTICAL PREDICTION DEFLECTION ANGLE
LPD—LATERAL PREDICTION DEFLECTION ANGLE
TPC—TOTAL PREDICTION CORRECTION ANGLE
EPC—ELEVATION PREDICTION CORRECTION
APC—AZIMUTH PREDICTION CORRECTION
PP—PRESENT POSITION OF TARGET
FP—FUTURE POSITION OF TARGET
PE—PRESENT ANGLE OF ELEVATION OF SIGHT
PA—PRESENT AZIMUTH ANGLE OF SIGHT
V—VERTICAL
L—LATERAL

Figure 2—118. Geometry of Lead Computation.

changes necessary to align the sight with the future target position; they are the angles through which the sight mut be moved, in azimuth and in elevation, from the present target position to the future target position.

The movement of the sight necessary to follow the projection of the target path PP-FP (Figure 2-117) on the tangent plane is resolved into vertical and lateral components PP′-V and PP-L. These are measured as vertical prediction correction angle VPD and lateral prediction correction angle LPD. The angles lie in the vertical and lateral planes through the present target position.

It is emphasized that the vertical and lateral deflection angles VPD and LPD are not the same as the change in target azimuth and elevation correction angles APC and EPC (Figure 2-118).

Range is computed continuously, but no prediction corrections are made for any change in range between the present and future target position.

All ballistic and parallax computations by the computer are calculated separately as vertical and lateral deflections from the actual gun position and the future target position.

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These vertical and lateral deflections are measured in two planes, a vertical plane through the gun line, and a lateral plane which contains the gun line and which is perpendicular to the vertical plane through the gun line.

From the preceding discussion is seen that all ballistic and parallax corections are calculated as vertical and lateral deflections from the actual gun position to the future target position, while lead prediction is calculated as vertical and lateral deflections from the present line of sight to the future target position. The only possible correcting movements of the gun, however, are in elevation and azimuth. This necessitates conversion between these two sets of vertical and lateral deflection angles and the actual correction angles; this, is the function of the axis converter and the total-correction unit.

The free-gyro computer computes prediction from the fact the target will move through very nearly the same angle in any two consecutive equal intervals of time. This angle is determined during one such interval. In this system, the guns fire during the first interval, the projectiles raking across the target's path, as the theoretical solution is reached and held during a recomputing cycle.

Source of Compuier Inputs. All inputs to the computer are supplied from the following sources:

The altitude-and-airspeed handset supplies a signal proportional to the windage effect on the projectile.

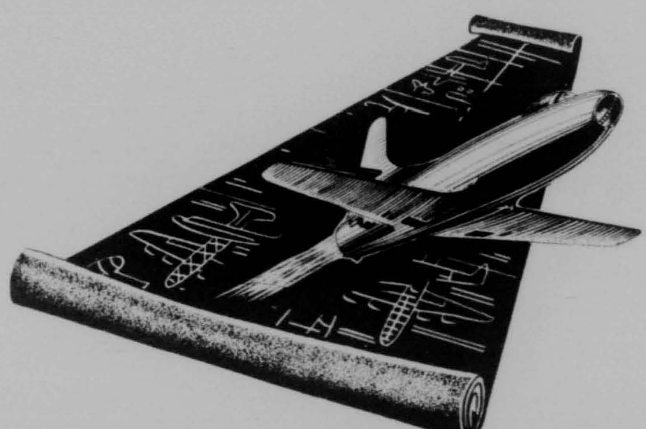
The Selsyn control circuit to the computer supplies sight-elevation, sight-azimuth, gun-elevation, and gun-azimuth position indications.

The radar set supplies range information for the tail system, only.

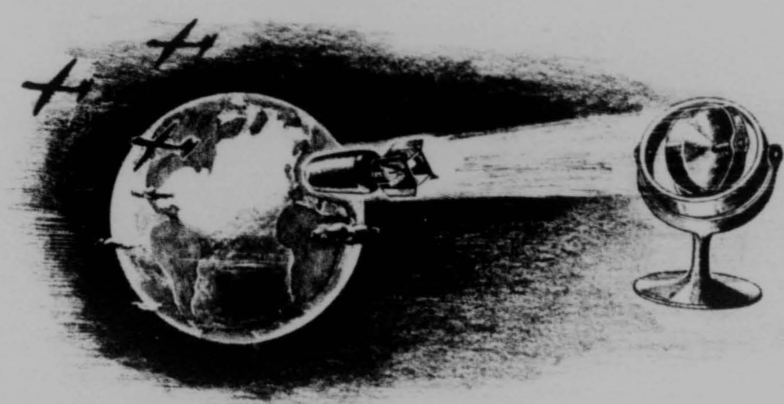
The retiflector sight on the sighting station supplies range information for all turrets other than the tail turret.

A gyroscope, which is mounted on the antenna assembly (radar) or the sighting station, supplies lead information. The gyroscope measures the angular movement of the tracking axis in the vertical and lateral planes during a time-of-flight interval.

The computer itself calculates the gravity correction. This is added to the ballistic and parallax corrections and to the lead prediction, to give the total-correction output which is required by the gun turret in order that its projectiles hit the target.



CHAPTER 3—GYRO PRINCIPLES, THEORY OF BOMBING



SECTION I—GYRO PRINCIPLE—PHENOMENA OF THE GYROSCOPE

1. GENERAL

The word gyroscope is of French origin. One of the first authorities on the subject of gyroscopic phenomena was Leon Foucault, a French scientist, who in 1852 succeeded in producing a gyroscope with which he was able to study the earth's rotation. There is nothing mysterious about the gyroscope, more commonly called "gyro". All of the practical applications of the gyro are based upon two fundamental characteristics, namely "gyroscopic inertia" and "precession". A gyroscope is simply an accurately-balanced, spinning flywheel. The flywheel spins about its central axis, which passes through its center of gravity, and it is so mounted that it is free to turn or tilt in any direction about this center of gravity and will maintain its spin axis in the same direction unless some outside force is applied to it (see Figure 3-1).

2. CHARACTERISTICS OF THE GYROSCOPE

Rigidity

One of the gyroscope's two special characteristics is gyroscopic inertia or rigidity. Gyroscopic inertia, or rigidity in space as it is sometimes known, is the tendency of any rotating body to preserve its plane of rotation. For example, a hoop when set in motion will keep on rolling approximately in a straight line if undisturbed, instead of tipping over as it would if not revolving. This characteristic is the result of the action of forces affecting the state of rest and motion of a gyroscope in the manner expressed by Newton's first law of motion. This law states that a body continues in its state of rest or of uniform motion in a straight line, unless it is compelled by forces to change that state. This

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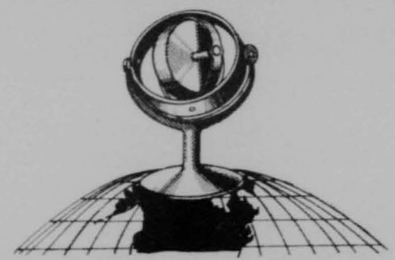

Figure 3—1. Gyroscope.

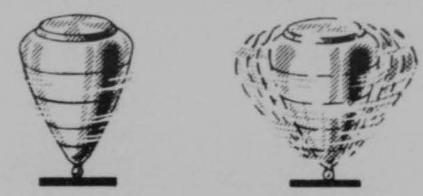

Figure 3—2. Characteristics of a Gyroscope.

law, as applied to a rotating wheel, may be expressed by stating that a rotating wheel tends to maintain its plane of rotation in space and the direction of its axis in space. Three factors determine a gyroscope's strength or amount of rigidity: the weight of its wheel or rotor, the distribution of its weight, and the speed at which the rotor spins. Thus rigidity may be increased by adding to the weight of the rotor; a gyro with a heavy rotor will have more rigidity than one with a light rotor if their speed is exactly the same. Increased rigidity may be obtained if the weight of the gyro is distributed to the outer rim of the wheel or rotor, as far from the spin axis as possible, yet without actually increasing the weight of the rotor. Rigidity is also increased if the speed of the rotor is increased. A slowly spinning rotor gives the gyro little or no rigidity. An example is a boy's top which wobbles and then falls over on its side when its speed of rotation decreases (Figure 3-2).

Apparent Precession

Because rigidity makes the gyro's spin axis fixed in space, (the axis will point in a fixed direction) the earth, which is actually rotating, turns under the gyro, and the axis of the gyro appears to tilt. (See Figure 3-3.) A gyro whose axis is vertical at six o'clock in the morning appears to be horizontal at noon and upside down at six o'clock in the evening. This creates the illusion that the gyro has turned over, end for end, and a complete revolution will be made every twenty four hours. Actually, however, the gyro has maintained its position in space, and the earth has moved around it. This movement of the earth in relation to the gyro is called "apparent precession". The greatest amount of apparent precession is at the equator. There, in four minutes a gyro will apparently precess 17.45 mils. The amount of apparent precession decreases as the gyro is moved toward the north or south poles, where apparent precession is zero. It can be determined, in mils, the amount of apparent precession that takes place in four minutes in any latitude, by using this equation: 17.45 x cosine of the latitude. Apparent precession of a gyro makes it unfit for use as a reference over an extended period of time without some sort of compensating or correction mechanism. Over a relatively short period of time, however, a gyro may be used to establish a satisfactory reference, as in the various gyro-stabilized instruments used by the armed forces today. One should remember that in apparent precession, the earth moves in relation to the gyroscope. However, the gyroscope may be made to move in relation to the earth, and this is called "induced precession".

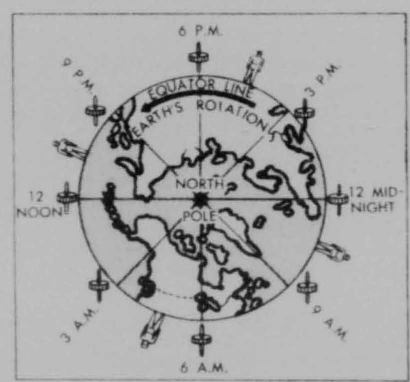

Figure 3—3. Apparent Precession.

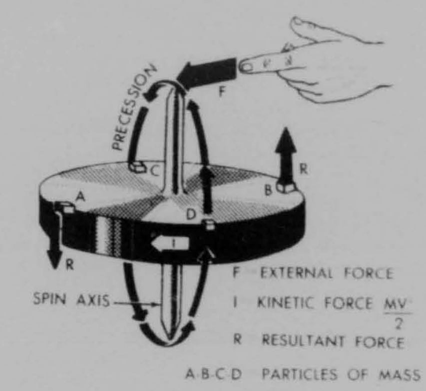

Figure 3—4. Gyroscopic Precession.

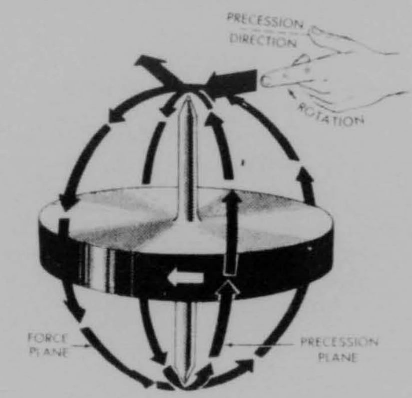

Figure 3—5. Hand Rule for Precession.

Induced Precession

The rigidity of a gyroscope resists any force applied which would tip its axis in any direction. When enough of a tipping force is applied to overcome this rigidity, the spin axis will tip, but not in the direction of the force, as would be expected. Instead the axis tips at right angles to the applied force and in the direction of the gyro's rotation. This peculiar action is called gyroscopic precession and is also exhibited by the rolling hoop. If we wish to change its direction of travel, we do not press against the rim at the front or back, but at the top, as though we intended to tip it over about an imaginary horizontal axis. The hoop resists this pressure and turns about a vertical axis which is at right angles to the axis about which the pressure was applied. Precession may be illustrated by applying a force or pressure to the gyro about the horizontal axis. It will be found that the applied pressure meets with resistance and that the gyro instead of turning about its horizontal axis, turns or precesses about its vertical axis. Similarly, if we apply a pressure about the vertical axis the gyro will precess about the horizontal axis. If there were a complete absence of inertia and friction about the precessional axis, the rate of precession would be such that the resistance of the gyro would be exactly equal to the applied pressure at any instant. No movement from this pressure could ensue until the gyro precessed so that its plane of rotating coincided with the plane of the plane of the applied pressure. Then the precession would cease and with it all resistance to the applied pressure. For explanatory purposes (see Figure 3-4), consider the effect of this external horizontal force, applied to the top of the gyro spindle, on selected particles of mass, A, B, C, and D, which at a given instant are in the position shown. The force applied at the top of the spindle, tending to tip the spindle about the force axis is equivalent to a downward force acting on particle A, and an upward force on particle B. No force, however, is exerted on particles C and D because they are in the force axis. However, these particles are spinning rapidly, and they are influenced by the forces of inertia which tend to make the particles move in a straight line I as shown at A and B. The resultant of the two forces I and F acting on particle A is represented by the arrow R, which can be seen to slant downward while the resultant of the forces at B slants upward. Therefore, as particle A revolves, it drops lower and lower until it reaches point C. At this point the applied force ceases to have a downward effect and begins to have an upward effect on particle A. Particle B reacts in the opposite way, with the result that the entire gyro tips at right angles to the applied force.

3. HAND RULE FOR PRECESSION

A good way to remember the direction in which a gyro will precess when an external force is applied is by hand rule shown in Figure 3-5. Using either hand, place the fingers in the direction of rotation and extend the index finger in the direction of the applied force. The thumb will then extend in the direction of precession. It is apparent from the preceding explanation of gyro precession, that if a force were applied to the gyro at the center of gravity it would not act to tip the gyro axis from its established position and therefore, no precession would take place. Thus a spinning gyroscope can be moved in any direction as easily as a gyro at rest, provided its spin axis remains parallel to its original position in space. The gyro, therefore, provides stability only against tipping its spin axis. It is also apparent that a spinning gyroscope can be used to provide stabilization only in planes containing its spin axis, and for complete stabilization in every plane, two gyroscopes, having their spin axis at right angles to each other, are required. This is why, as will be discussed later, both a horizontal gyro (in the stabilizer unit) and a vertical gyro (in the bombsight unit) are required to give complete stabilization to the optical system of the bombsight.

SECTION II—THEORY OF BOMBING

1. INTRODUCTION

It is impossible to outline briefly the improvements that have been made in bombsights and other bombing equipment in the past twenty-five years. To design an accurate bombsight required years of trials. Discouragements were many and progress slow. With the bombsight completed it took the best efforts of American industry to learn how to build these intricate devices to the close tolerances required, and in the large numbers called for by global war. Avoid the common impression that the bomb-sight is a superhuman, magic-brain device. True, it is an ingenious, precision mechanism, but it definitely is not a miracle machine which requires a miracle man to operate it; nor is it a device which relieves its user of all responsibility. What it does is to solve understandable problems in an understandable manner. Other equipment used includes the electronic copilot, which holds the airplane on its course; the computers, which save the time and trouble of making paper and pencil calculations; the intervalometer, which enables the bombardier to drop a train of accurately-spaced bombs, and oxygen equipment which makes possible ascents to altitudes higher than man ever went before. With the modern bombsight, that great group of men, the bombardiers, have proved beyond question the ability of the air force to pin-point ammunition dumps on tiny atolls in the Pacific, to destroy ships at sea, to blast bridges and communication lines far beyond artillery range, and to lay a ruinous pattern of fire and explosives on ANY of the enemy's industrial areas.

2. THEORY OF BOMBING

Before the invention of airplanes, the principal means of dropping explosives upon the enemy was the long-range cannon. An airplane, in effect, advances the range of a cannon. Bombing is really aerial artillery. To make a shell drop on a certain point, a cannon must hurl it up into the air, so that the path of the shell, or the trajectory, describes a wide arc in its flight through the air. The essential difference between firing a shell and dropping a bomb is that the airplane carries the bomb up into the air and releases it at the highest point of the trajectory. From that point on, the bomb follows the same downward path as the shell (see Figure 3-6). To make the bomb hit the target, the only thing that has to be done is to find the proper point in space from which to release it. Actually, the bombsight will find this point and release the bomb, provided that the proper data are put into it. A

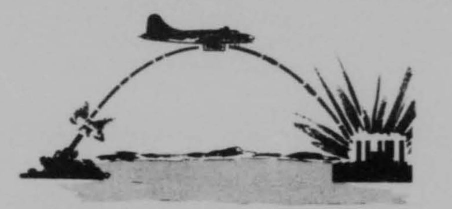

Figure 3—6. Aerial Artillery.

thorough study of bombing theory, however, will show what data must be set into the sight, how it is set in, and how the bombsight uses it to solve the bombing problem. The bombing problem has two parts; the course problem and the range problem. Course means that the bomb must travel in the right direction, that is, toward the target. Range means that it must be released the correct distance back from the target or over it. The course problem is fairly simple. A bomb always falls in the direction in which the airplane is headed at the moment of release. Therefore, the course problem is solved by putting the airplane on the correct heading. To understand the range problem, something must be known about falling bodies.

3. FORCES ACTING ON THE BOMB

General

The moment a bomb is released from an airplane, a number of forces begin acting upon it. These forces are: **gravity; airspeed; air resistance,** and **wind.** (See Figure 3-7). The result of these forces determines the path the bomb will follow and the point of impact.

Gravity pulls the bomb toward the earth at a continually increasing speed. It exerts the same force on all bodies, whatever their size, shape, or weight.

True Airspeed

At the same time that gravity is pulling the bomb downward, velocity is driving it forward. The airplane is traveling at a definite speed with respect to the air, and since the bomb is a part of the airplane up to the moment of release, it leaves the airplane with the same forward velocity. In bombing, this forward velocity of the airplane and the bomb relative to the air is called true airspeed (TAS). Gravity and true airspeed are acting on the bomb at the same time. During the time between release and impact the bomb follows a path between the direction of these two forces. This time is called actual time of fall (ATF).

Air Resistance

The third force affecting the bomb in its flight is one which acts against the first two. This force is air resistance. While true airspeed is driving the bomb forward, the air through which the bomb moves is resisting this motion. In other words, the air pushes back against the bomb, causing it to lag behind the airplane. The distance on the ground resulting from this resistance to the forward motion of the bomb is called horizontal lag. In the same way, air resistance acts against the force of gravity. This resistance tends to keep the bomb in flight longer. During the extra time required for the bomb to fall, the airplane continues to move forward. The distance on the ground over which the airplane travels during this extra time is called vertical lag.

4. BOMBING TERMINOLOGY

Trail

The sum of these two distances on the ground is called trail (T). This is a good name for it, since it is the distance the bomb has trailed behind the airplane that dropped it. Trail is the horizontal distance measured on the ground from the point of impact to a point directly beneath the airplane at the instant of impact. The amount of trail for various bombing altitudes, true airspeeds, and types of bomb has been determined by experience and is given in bombing tables. Trail is the result of several forces which are acting on the bomb. While true airspeed is driving the bomb forward, air resistance is tending to hold it back; while gravity is pulling it down, air resistance is tending to hold it up. If true airspeed increases, the resistance of the air increases; thus the horizontal lag is greater.

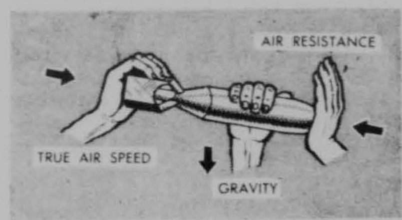

Figure 3–7. Forces Acting on Bomb.

Therefore, as true airspeed increases, trail increases. In the same way, if the downward velocity increases, the resistance of the air to that force increases and the vertical lag is greater. Since the downward velocity depends on the bombing altitude from which the bomb is dropped. As bombing altitude increases, trail increases. The amount of resistance which the air offers to the bomb depends on the size and shape of the bomb. Ordnance engineers classify bombs into different types according to the ballistic coefficient of the particular bomb, which means the relative amount of resistance the air offers to it. A bomb with a high ballistic coefficient falls faster and with less trail than a bomb with a low ballistic coefficient. Therefore, as ballistic coefficient increases, trail decreases.

Actual Time of Fall

The actual time of fall (ATF) of the bomb depends primarily on the exact height of the airplane above the target, or the vertical distance which the bomb must fall. It is also affected by true airspeed and bomb ballistics. The actual time of fall for each bombing altitude, true airspeed, and type of bomb has been determined by trial and error and is given in bombing tables. **ATF increases as bombing altitude increases; true airspeed increases; ballistic coefficient decreases.** Trail and actual time of fall are the two factors which must be set into the bombsight. The actual time of fall is set into the M-Series bombsight as a disk speed, but when some other sights are used, the actual time of fall is set in directly. Trail is set into the bombsight as a mil value. The tables give the correct actual time of fall or the correct disk speed for each bombing altitude, true airspeed, and type of bomb. Similarly, the tables give the correct trail for each bombing altitude, true airspeed, and type of bomb. Therefore, before the sight can do anything, the bombing altitude, true airspeed, and type of bomb must be accurate. When correct trail and actual time of fall have been obtained from the tables and have been set into the bombsight, it must be synchronized for course and range. If these few things are done correctly, the bombsight will automatically solve the bombing problem. It will find the correct point in space for the bomb release, and will release the bomb at that point. (See Figure 3-8.) Before considering wind, the fourth and final force on the bomb in its downward flight, fundamental bombing terms must be understood.

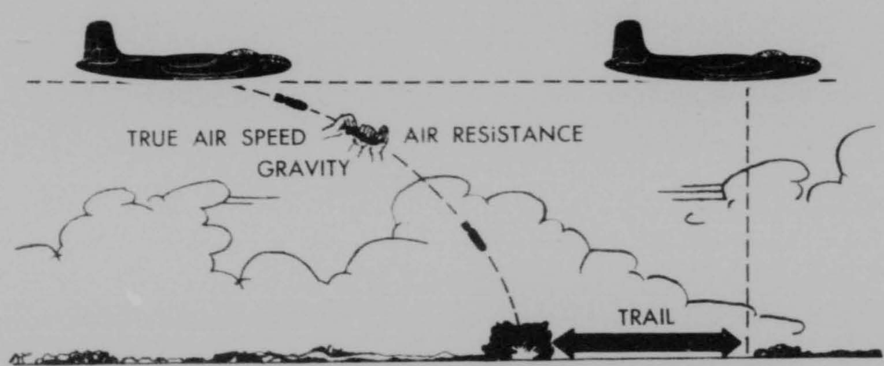

Figure 3–8. Bomb Release and Trail.

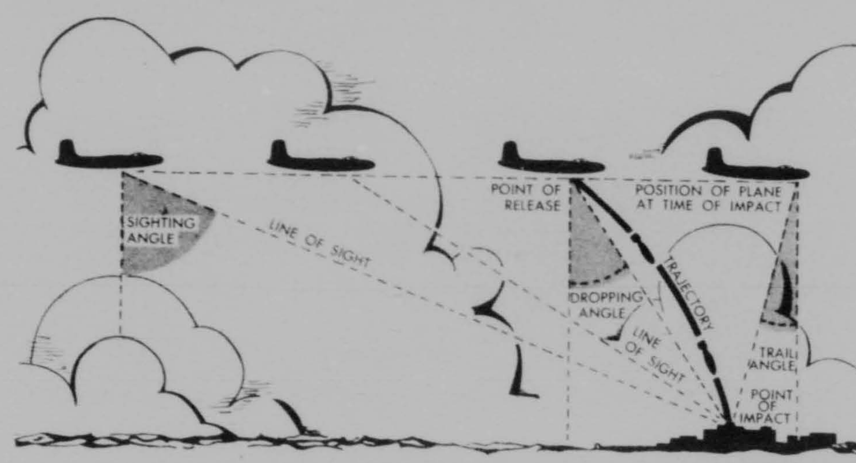

Figure 3–9. Factors in Bombing.

Whole Range and Groundspeed

Whole range (WR) is the horizontal distance traveled by the airplane from the moment the bomb is released until the bomb strikes the ground. To measure the distance covered by a moving object in a given time, the time is multiplied by the rate at which the object is moving. Whole range is measured on the ground. Therefore, the rate used is the rate at which the airplane is moving with respect to the ground. This rate is called groundspeed (GS), and in computing whole range, groundspeed must be in feet per second. The time used is the actual time of fall, and it is given in seconds. Therefore:

$$WR = GS \text{ (ft/sec) } X \text{ ATF}$$

A bomb is dropped from an airplane traveling at a groundspeed of 150 miles per hour. The bomb takes 20 seconds to reach the ground. In order to find the whole range, the groundspeed of 150 miles per hour must first be changed to feet per second. To do this, multiply 150 by:

$$\frac{5{,}280 \text{ (ft in a mile)}}{3{,}6000 \text{ (sec. in an hr.)}} \quad \frac{88}{60} \text{ or } \frac{22}{15}$$

The groundspeed in this problem is therefore 220 feet per second. Then $220 \times 20 = 4{,}400$ ft. whole range. In other words, the airplane flies 4,400 ft. while the bomb is falling.

Actual Range

Actual range (AR) is the horizontal distance that the bomb travels from the moment of release until the moment of impact. Since the bomb lags a certain distance behind the airplane (trail) actual range can be found by subtracting trail from whole range.

$$AR = WR - T$$

If the whole range is 4,400 ft. and from bombing tables, it is found that the trail is 270 ft. the actual range is 4,130 ft. While the airplane is traveling 4,400 ft. forward, the bomb travels only 4,130 ft. forward. See Figure 3-9.

Line of Sight

Whenever the target is looked at through the bombsight, vision follows a line, from bombsight to target, which is called the line of sight. As the airplane moves toward the target, the line of sight changes. When the proper course toward the target has been set up the actual range has yet to be found, that is, the correct distance back from the target that the bomb must be released in order to score a hit. If the proper data is set into the bombsight, it solves the problem automatic-

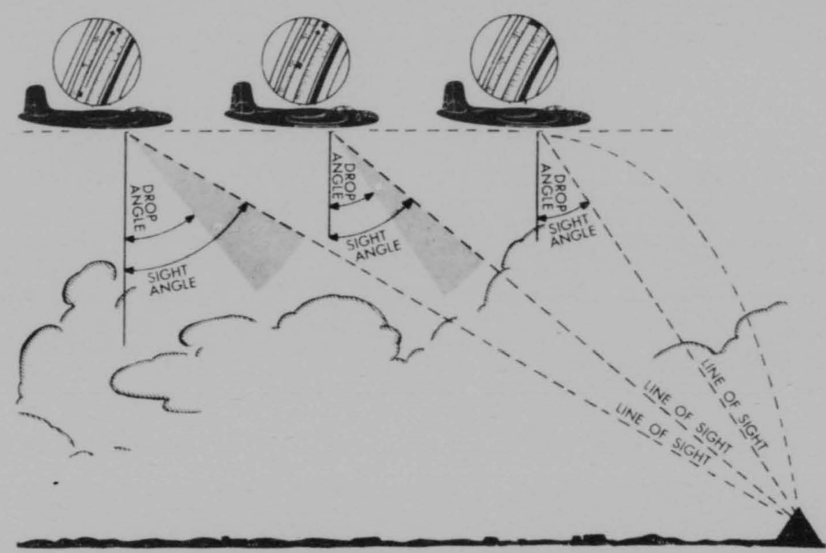

Figure 3–10. When Sighting ∠ Equals Drop ∠, Bomb is Released.

ally. It measures an angle which subtends actual range, thereby locating the proper point in space for the bomb's release.

Sighting Angle

To do this, the bombsight sets up a vertical line of reference between iself and the ground. The angle between this vertical reference and the line of sight at any instant is called the sighting angle. As the airplane approaches the target, the line of sight sweeps toward the vertical and the sighting angle grows smaller.

Dropping Angle

The particular sighting angle set up by the bombsight at the instant of release is called the dropping angle (Drop ∠). The dropping angle is the angle formed between the line of sight and the vertical reference at the instant the bomb drops from the airplane.

True Vertical and Bombsight Vertical

If the bombsight is operated correctly, it will establish as the vertical line of reference a line which is exactly perpendicular to the ground. If the bombsight is not operated correctly, the line of reference it sets up will not be true vertical. The sighting angle and the dropping angle are measured from the vertical reference set up by the bombsight, whether this is the true vertical or not. See Figure 3-10.

Range Angle

The range angle is the angle between the line of sight and the true vertical. At the instant of release, this angle differs from the dropping angle by the amount the vertical reference is out of the true vertical.

Actual Range Angle

The actual range angle (AR ∠) is the angle which subtends the actual range of the bomb. This means that the lines which form the angle strike off on the ground the actual range distance. If the bombsight sets up to a true vertical reference and the bombing problem has been properly solved, the dropping angle is the same as the actual range angle and also subtends the actual range of the bomb.

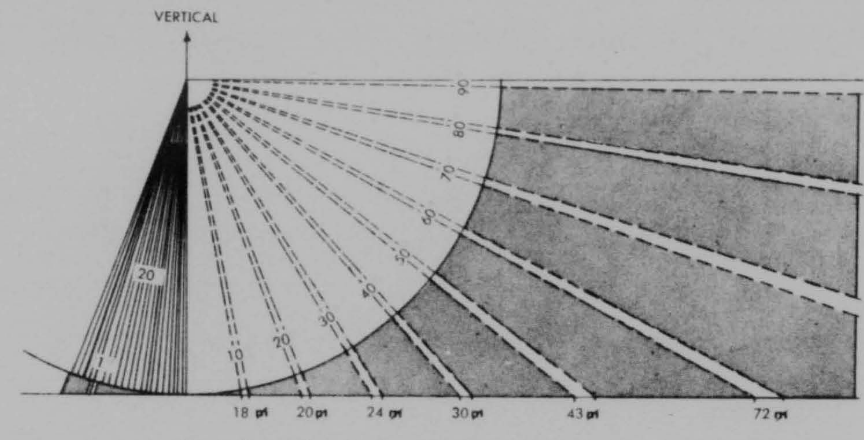

Figure 3–11. Dropping Angle Tangent.

Whole Range Angle

The whole range angle (WR ∠) is the angle which subtends whole range. It is measured from the true vertical at the instant of release.

Trail Angle

The angle which subtends trail is called the trailangle (T ∠). In bombing, trail is given and used in terms of mils.

Tangent Values of Angles

Angles can be measured by using what is called the tangent of the angle, and this is the method the bombsight uses. The tangent of an angle in a right triangle is the number resulting when the length of the side opposite the angle is divided by the length of the side adjacent to the angle.

$$\text{Tangent} = \frac{\text{opposite side}}{\text{adjacent side}}$$

Reading Angles From the Bombsight

The particular tangent which can be read from the bombsight is the tangent of the dropping angle (Tan Drop ∠). The side opposite the dropping angle is the actual range, and the side adjacent to the dropping angle is bombing altitude (BA). (Figure 3-11). Therefore:

$$\text{Tan Drop}\angle = \frac{AR}{BA}$$

In the same way:

$$\text{Tan T}\angle = \frac{\text{T (in ft.)}}{BA}$$

Since the trail angle is comparatively small, it is measured in mils rather than in degrees. A mil is an angle whose tangent is 0.001. An angle of 3 mils has a tangent of 0.003; an angle of 35 mils has a tangent of 0.035. One mil subtends a distance on the ground equal to 1/1,000 of the BA. At 1,000 ft. BA, 1 mil of trail subtends 1 ft. on the ground. At 8,000 ft., 50 mils of trail subtends 400 ft. Therefore:

$$(\text{Tan T}\angle) = \frac{\text{T (in mils)}}{1{,}000}$$

$$\text{T (in ft.)} = \frac{\text{T (in mils) BA}}{1{,}000}$$

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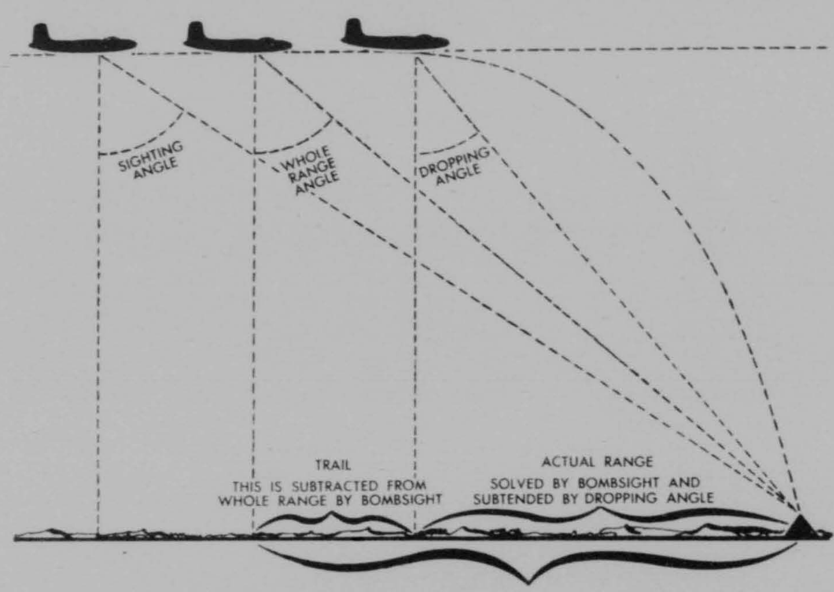

Figure 3—12. Whole Range Solved by Bombsight from GS x ATF.

Since whole range equals actual range plus trail, then:

$$\frac{WR}{BA} = \frac{AR}{BA} + \frac{T}{BA} \quad \text{Therefore:}$$

$$\frac{WR}{BA} = \text{Tan Drop} \angle + \text{Tan T} \angle = \text{Tan WR} \angle$$

When the whole range that the bombsight has measured is desired it must be computed from the tangent of the whole range angle which subtends it. The tangent of the whole range angle is found by adding the tangent of the trail angle to the tangent of the dropping angle. The tangent of the dropping angle can be read directly from the bombsight. The trail angle is read and can be converted to a tangent value by dividing by 1,000. The tangent of the whole range angle is equal to the whole range divided by the bombing altitude. Therefore:

$$NR = \text{Tan WR} \angle \times BA$$

5. SOLUTION OF THE RANGE PROBLEM

It is necessary to know the bombing altitude, true airspeed, and type of bomb to find from the bombing tables the trail and actual time of fall to set into the bombsight. By keeping the line of sight on the target, groundspeed is solved. This is called range synchronization. The actual time of fall set into the bombsight is automatically multiplied by the groundspeed obtained through synchronization to solve for whole range. During this operation the trail that was previously set into the sight is automatically subtracted from whole range, leaving the measurement of actual range. During this operation the bombsight sets up the dropping angle which subtends this actual range. When sighting angle reaches dropping angle, the bomb is released automatically. See Figure 3-12.

Headwinds and Tailwinds

In addition to gravity, forward velocity,

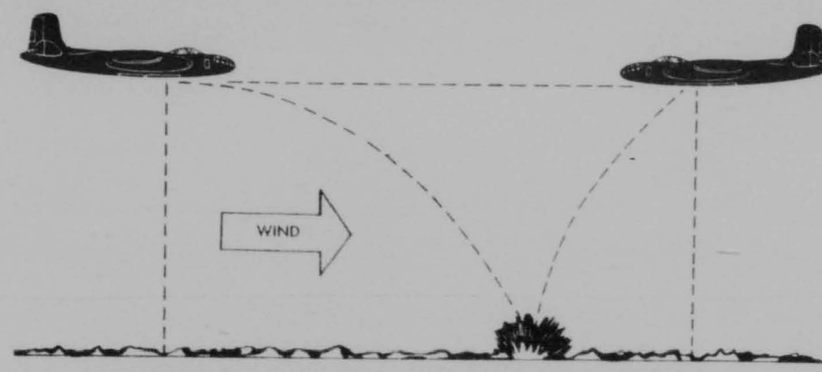

Figure 3—13. Solution of the Range Problem.

and air resistance, there is a fourth force acting on the bomb in its flight and affecting its trajectory. This is the speed of the wind. Consider first the simplest wind conditions; tailwinds and headwinds. The first thing to notice about a headwind or tailwind is that it does not affect the true airspeed of the airplane. Since trail depends only on true airspeed, bombing altitude, and type of bomb, neither a headwind nor a tailwind has any effect on the amount of trail. Groundspeed is the factor which is affected by a headwind or a tailwind. If an airplane is flying at a true airspeed of 150 miles per hour, with a tailwind which pushes the air forward at 10 miles per hour, then the airplane's speed over the ground is 160 miles per hour. Since whole range is found by multiplying groundspeed (in feet per second) by the actual time of fall, an increase in groundspeed causes an increase in whole range. Actual range is also increased, since actual range is found by subtracting trail from whole range. Therefore a tailwind causes an increase in whole range and a corresponding increase in actual range. See Figure 3-13. When actual range is increased, the bomb must be dropped at a greater distance from the target in order to hit it. This means that the dropping angle must be greater. When there is a tailwind the bombsight sets up a dropping angle with a larger tangent. When the airplane flies directly into a headwind, all these results are reversed. The groundspeed is less, and the actual range is smaller. The bombsight therefore sets up a smaller tangent of the dropping angle.

Crosswinds

When the wind comes from any direction except from dead ahead or directly behind the airplane, drift enters the bombing problem. Wind is the movement of the entire body of air surrounding the airplane. When the wind moves to the right, the airplane moves to the right. Similarly, if the body of air is moving to the left, the movement of the airplane is described as left drift. To make good a certain path over the ground (true course) when there is a crosswind, the pilot crabs the airplane into the wind. That is, he heads the airplane upwind sufficiently to compensate for the effect of drift. The angle formed between true heading and true course is called the drift angle. At the moment of release, true airspeed is driving both the airplane and the bomb in the direction of heading. Immediately on release, air resistance begins to reduce the forward velocity of the bomb. The engines, however, continue to drive the airplane forward at the same true airspeed as at bomb release. The speed of the wind causes both airplane and bomb to drift the same distance away from the true heading. Therefore, the bomb always

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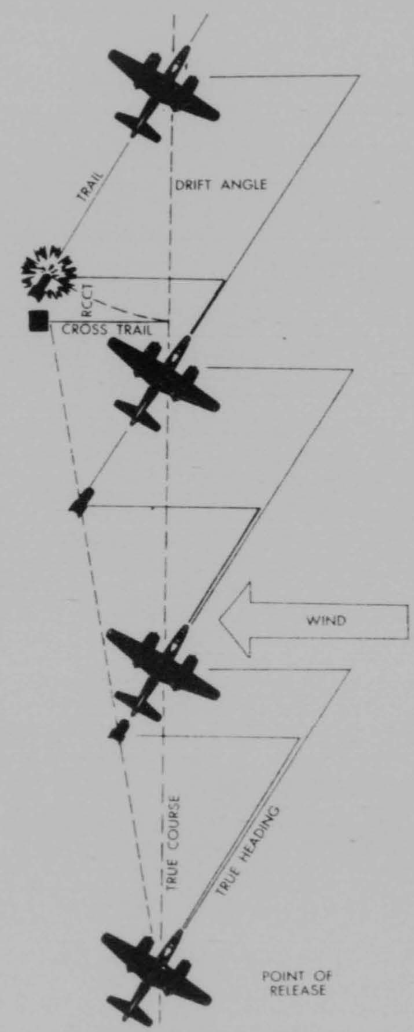


Figure 3—14. Influence of Crosswind on Bombing.

lags behind the airplane in the line of heading. The bomb will strike the ground behind the airplane, along the longitudinal axis of the airplane, and downward of true course. See Figure 3-14.

Crosstrail

If the airplane made good a true course which would pass directly over the target (a collision course), the bomb would strike the ground downwind of the target. The airplane must, therefore, make good a true course upwind of the target. The distance between the true course of the airplane and the collision course is called crosstrail (CT). Crosstrail is measured from the point of impact to the true course. The bombsight automatically measures crosstrail. Crosstrail depends on trail and drift. To make its computation, the bombsight uses what is called the sine of the drift angle. The sine of an angle in a right triangle is the sine of the drift angle. The sine of an angle in a right triangle is the number resulting when the opposite side is divided by the hypotenuse. The side opposite the drift angle is the crosstrail; the hypotenuse is the trail. Hence the sine of the drift angle is the crosstrail divided by trail. Therefore:

$$CT = T \times \text{Sin Drift}$$

The bombsight can compute crosstrail because trail has been set into it. Automatically the drift angle has been set up when the course is set. Naturally, if there is no drift there will be no crosstrail. In the same way if trail is not set in, the bombsight cannot compute crosstrail. Therefore trail MUST be set; if not the bomb will fall not only short but also downwind of the target.

RCCT

One final fact about the effect of crosswind on the bombing problem must be noticed. In the crosstrail drawing, Figure 3-14, the point of impact of the bomb is shown a small distance over the target. Although the distance is exaggerated in the drawing, nevertheless this error is always present in all computations performed by modern bombsights whenever a crosswind is present. The error is called range component of crosstrail (RCCT). It results from the fact that the bombsight measures trail along the course of the airplane,

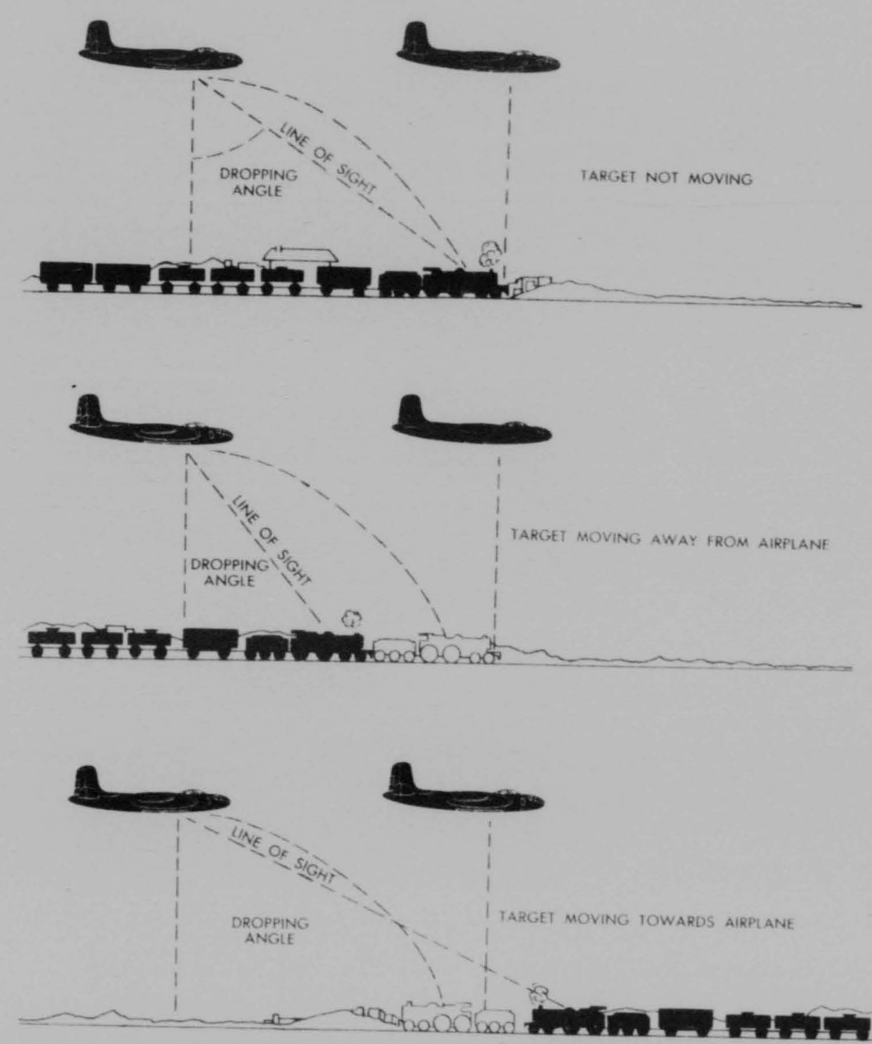


Figure 3—15. Bombing Stationary and Moving Targets.

whereas when there is a crosswind, trail actually occurs along the line of heading. When there is no crosswind, heading and course coincide; there is no crosstrail and no RCCT. But when wind and crosstrail exist, the bombsight still measures trail along the course. If the distance is measured from a point on the ground directly beneath the airplane at the moment of impact back along the course to a point opposite the target, the result is the trail as solved for by the bombsight. But if this same distance is measured back along the heading of the airplane, this trail distance does not reach the target. Instead, it reaches a point on the collision course ahead of the target. The distance from the target to this point of impact ahead of the target is the range error "over", known as RCCT. The equation for computing RCCT is:

$$RCCT = T\ (1 - \text{Cos Drift } \angle)$$

The RCCT depends on trail and the amount of drift. In low and medium-altitude bombing, trail and drift are usually small enough that the "over" caused by RCCT is negligible. RCCT produces significant errors when a high-speed bomber, flying at a high altitude, encounters a large drift. A moving target is often the object of attack. If the attack is made on a target which is moving in a straight line at a constant speed, no new element is introduced into the bombing problem. A target moving away from the airplane in the same line as the airplane's course presents the same problem as a stationary target when a headwind is blowing. Similarly, a target moving toward the airplane along the course is like a stationary target when a tailwind is blowing. Also a target moving in a straight line across the course presents the same problem as a stationary target with a crosswind blowing from the direction opposite to that in which the target moves.

A bombsight develops whole range, actual range, and dropping angle by analyzing the speed of closure between itself and the target, that is, the speed at which the distance between them is closed. When the target is stationary, the speed of closure is the same as the groundspeed of the airplane. When the target is moving, the speed of closure is the groundspeed of the airplane plus or minus the groundspeed of the target. When an airplane traveling at groundspeed of 150 miles per hour is overtaking a train retreating at 50 miles per hour, the airplane is actually closing with the train at a speed of 100 miles per hour. The bombsight solves for this speed of closure in setting up the dropping angle. When the train approaches the airplane, the speed of closure is 200 miles per hour and consequently the dropping angle is larger. See Figure 3-15. If the train moves in a straight line across the track of the airplane, the bombsight handles the situation just as if the target movement were drift caused by a crosswind. In fact, in setting up the course there is no difference between a left drift and an actual target motion to the right. In either case, the airplane must be crabbed to the right and a course set up to right of target. If the target is moving diagonally across the course and at the same time a crosswind is blowing, it would be very hard to determine the speed of closure mathematically. The bombsight automatically solves it and determines the correct course and dropping angle.

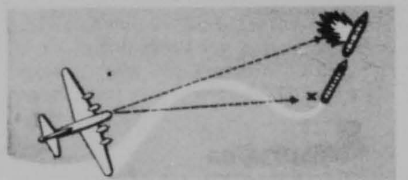


Figure 3–16. Bombing a Maneuvering Target.

However, there are two situations involving moving targets which the bombsight cannot handle adequately. First, if the target keeps changing its speed, the bombsight cannot synchronize for rate or determine the amount of crab required, and thus cannot set up the correct course of dropping angle. Second, if the target does not move in a straight line, the bombsight cannot set up either course or dropping angle accurately, since it has no means of predicting where the target will be at the time of impact. When trying to bomb a target which is maneuvering, the important element in solving the bombing problem is the experience of AF bombardiers. They have discovered that to hit a maneuvering target aim must be to the rear of the target movement and inside its turn. See Figure 3-16.

SECTION III—SYNCHRONOUS METHOD OF BOMBING

1. NORDEN BOMBSIGHT

The Norden or M-Series bombsight is a synchronizing, precision instrument. Synchronization means adjustment of flight path and travel of the optical system so that the bomb will be released at the proper point. The Norden sight is of American design and construction. There are several models in use, among them, the M-6, M-7, and M-9. The even-numbered models use 12 volts direct current; the odd-numbered models use 24 volts. The reasons for the voltage difference is that the newer bombers have 24-volt circuits. These four models are very much alike in principal and operation. The parts and steps to the Norden sight are inter-dependent. Each of them should be learned thoroughly. From study of the bombing problem, it is known what the bombsight must do. One must keep the bombing problem in mind by remembering that the sight solves the bombing problem only of the correct data is set in and the sight is properly operated and maintained. See Figure 3-17.

2. SIGHTHEAD

The bombsight has two main units, the sighthead and the stabilizer. The sighthead is attached to the stabilizer by a pivoting connection and two locking pins.

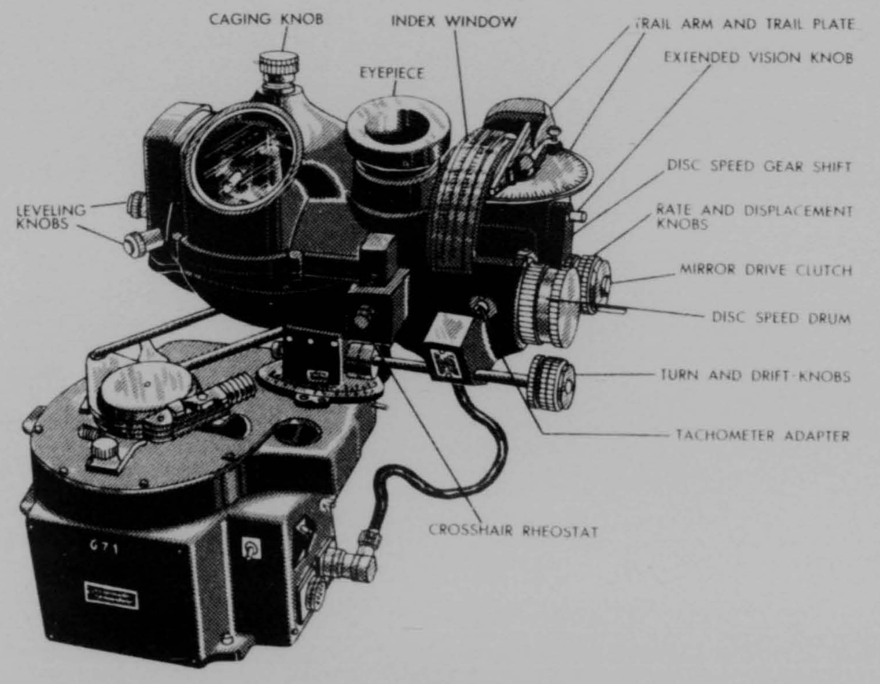


Figure 3–17. M-Series Bombsight.

Function

The sighthead's principal function, solving for range, is carried out by three main parts.

The rate end, which computes the exact release point for the bomb.

The optical system, through which the target is observed.

The vertical gyro, which stabilizes the optics so that roll and pitch of the airplane will not move the line of sight from target.

Solving the Range Problem

The rate end combines the values of ATF, groundspeed, and trail to compute the dropping angle. From the bombing tables are obtained the values of ATF and trail which are set into the sight. Then groundspeed remains the only unknown factor. The rate knob is used on the rate end to solve for it.

By turning on the rate motor switch, a motor is started which turns a disc in the rate end. The speed at which the disc turns represents ATF. The desired speed is set in by positioning the disc-speed drum. To find the correct disc-speed setting, the ATF is divided into the bombsight constant, 5,3000.

The disc drives a roller which can be moved from the center of the disc to its upper edge. When the roller is in the center of the rotating disc, it does not turn; when it is just off center, it turns very slowly. The farther the roller is moved from the center of the disc, the more rapidly the roller turns. The position of the roller on the disc is controlled with the rate knob and the trail arm.

Trail is set in by moving the trail arm to the desired position on the trail plate. This moves the roller out from the center of the disc a distance proportional to trail. Then looking through the optics, the rate knob is turned until the lateral cross-hair appears to stay on the target. By doing this, the roller has been moved an additional distance on the disc. This additional distance is proportional to actual range. The distance from the center of the disc of the roller is then proportional to whole range and the roller's speed of rotation is proportional to groundspeed.

At the same time that the rate knob positions the roller on the disk, it positions the dropping angle index on the tangent scale, thus setting up the correct dropping angle.

The roller drive is transmitted to a mirror which reflects the image of the target into the telescope. The mirror is hinged in such a manner that the roller drive changes the angle of reflection as the airplane approaches the target.

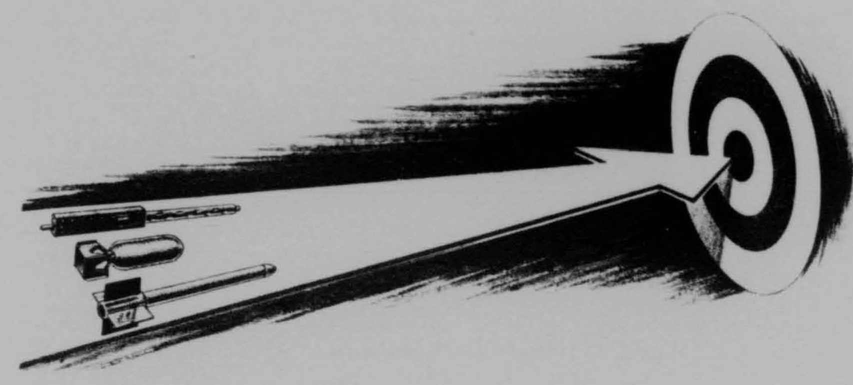
The sighting angle at any moment is shown by the sighting-angle index. The index can be seen on the degree scale in the index window.

When the sighting-angle index is exactly opposite the dropping-angle index, the sight automatically releases the bomb if the release lever is up. There are three types of release levers. One has to be held up manually. Another locks in the ON position when raised and has to be released after the bomb is released. The third, locks in the ON position and releases itself automatically after the bomb is released.

Before synchronizing, however, the line of sight must be made on the target. This is done manually. If at higher altitudes, the search knob is used which gives rapid displacement of the mirror for sighting angles from 70 degree to 0 degrees. When the target is picked up the mirror drive clutch is engaged to connect the drive of the roller to the mirror.

At lower altitudes, when more than 70 degrees forward vision is needed the extended vision knob is used which permits vision up to 90 degrees. When using the extended vision, the mirror drive clutch is not engaged until a sighting angle of 70 degrees is reached.

CHAPTER 4—SIGHT A-1B (GUN-BOMB ROCKET)



SECTION I—DESCRIPTION (GENERAL)

1. LIST OF COMPONENTS

The sight consists of the following units, (Figure 4-1), which are furnished by the manufacturer. Each sight is calibrated at the factory.

2. GENERAL DESCRIPTION

Purpose

The A-1B sight is an aircraft sight which automatically solves the fire control problems for gunfire from fixed guns, for bombing, and for rocketfire. The automatic feature enables the pilot to direct his full attention to the selected target. He must, however, fly the airplane so that a circular pattern of light, appearing on the windshield, is continuously superimposed on the target under attack. When this "tracking" action is performed correctly and smoothly, the airplane approaches a position from which its projectiles (shells, bombs, or rockets) will strike the target. In the case of gunfire or rocketfire, tracking should continue for four or five seconds, after which the pilot may close the firing switch. Bombs, however, may be released automatically by the sight when the airplane reaches the correct point on its approach.

Gunfire Function. The sight computes the required angle between the line of sight to the target and the boresight line of the fixed guns in the airplane. This prediction angle is generated as the resultant of two components. One, the elevation component, is the rotation of the airplane about the elevation axis of the sight. The elevation axis is perpendicular to the plane of symmetry of the airplane. The other, the deflection (or azimuth) component,

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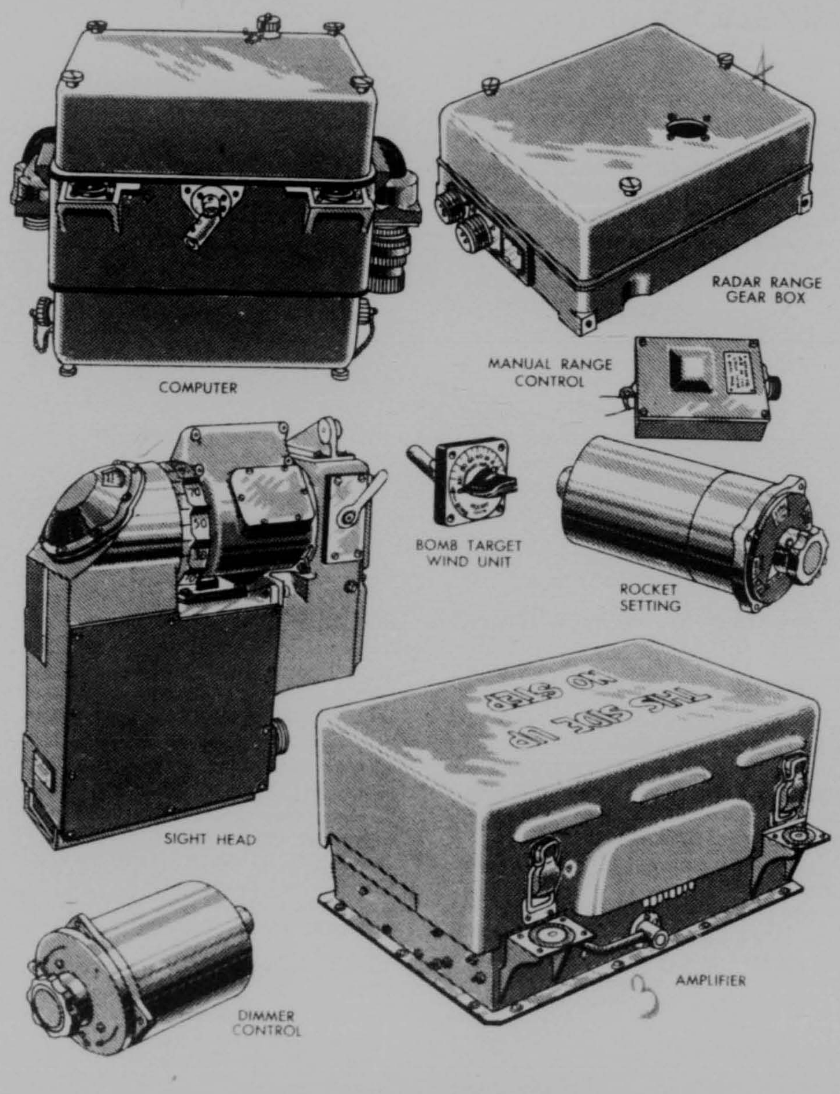

Figure 4–1. Type A-1B Sight (Gun-Bomb-Rocket) Components

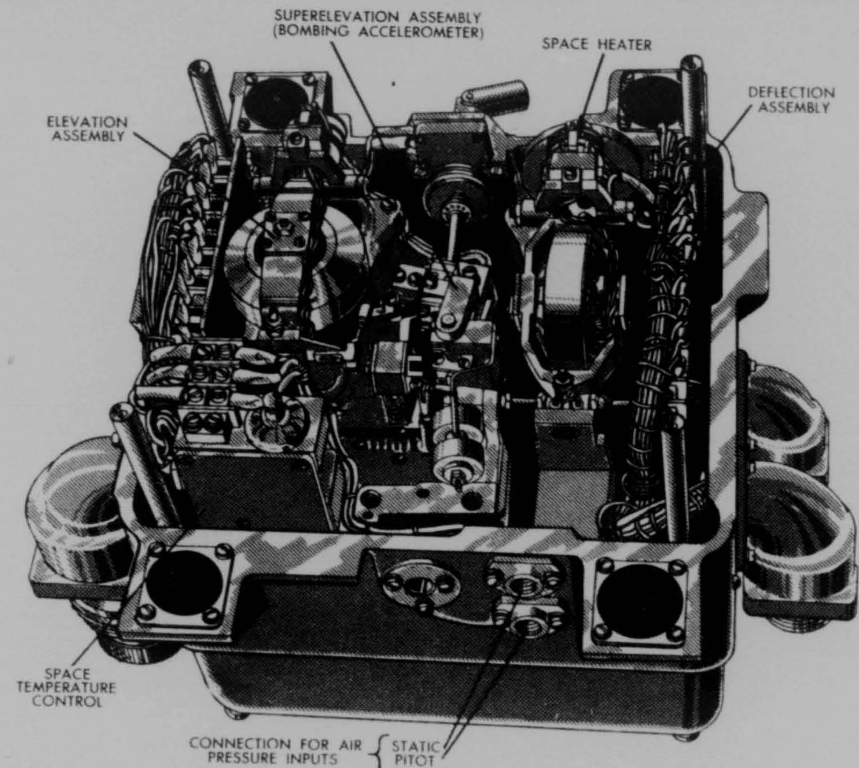

Figure 4–2. Computer, Top Cover Removed.

is the rotation of the airplane about the deflection axis of the sight. The deflection axis is in the plane of symmetry of the airplane perpendicular to the boresight line of the guns. It is necessary also for the sight to receive range data from an outside source, because the prediction angle increases with increased range. Under normal conditions, range is furnished by a radar set. If the radar set fails, the pilot may insert range into the sight manually.

Bombing Function. After the sight is set for this function, by adjusting the knob on the bomb-target wind unit, the sight operates automatically. The position of the reticle image requires the pilot to fly a downward path which becomes tangent to a bomb trajectory. The point of tangency is the bomb release point and is indicated to the pilot as a change in the pattern of the reticle image. Bombs are dropped automatically at this point, although the pilot may release them manually if desired. Less data is required for the bombing function than for gunfire. No range, altitude, or dive angle inputs are required.

Rocketfire Function. The sight furnishes automatic operation for rocketfire after adjustment of the knob on the rocket setting unit. This adjustment provides a constant reticle depression in elevation corresponding to the type of rocket to be used. Operation thereafter is similar to operation in the gunfire function.

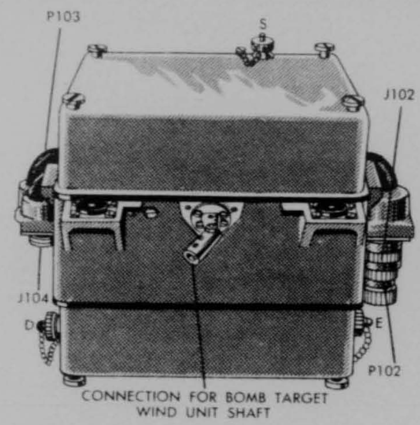

Figure 4–3. Computer, Rear.

Fixed Sight Function. The sight may be used as a fixed ring-sight by moving a lever on the sight head. When used in this manner no prediction angle is generated. The reticle image remains of constant size and at a fixed position on the windshield, not responding to airplane motion. As in other functions, however, the image is formed by a collimating lens (focused at infinity) and moderate motion of the pilot's head does not cause misalignment between reticle image and target.

General

The detailed description of the sight is closely allied to the discussion of operating principles given in section II. In the preparation of the remainder of this section, an endeavor has been made to avoid description that would require repetition with the presentation of operational information. Therefore, it is suggested that the reader might benefit by reference to corresponding subject matter in section II while reading the following paragraphs. The functional discussion in that section will supplement the physical description given here.

Components

The sight consists of the eight components listed in Figure 4-1. They are connected by flexible electrical cables, except for the computer and the bomb target wind unit, which are connected by a universal joint shaft. Consequently the location of the components, except for the two mentioned, need not be determined by the functional relationship between them. The sight head and computer, however, must be installed in proper relationship to the airplane. The sight head projects the reticle image on an optically flat section of the pilot's windshield. The computer contains the two gyros which provide the reference for calculation of the prediction angle.

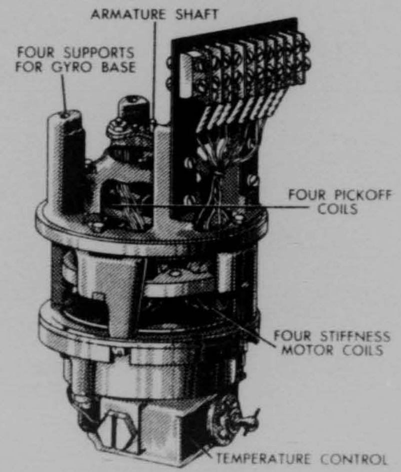

Figure 4–4. Elevation Assembly, Gyro Removed.

Computer. The computer (Figures 4-2 and 4-3) contains the principal mechanical components which compute the prediction angle for the three functions of the sight (gunfire, bombing, and rocketfire). The components are contained in a shock-mounted housing which is properly aligned with the airplane structure. The principal components are the elevation assembly (Figure 4-4), the deflection assembly and the superelevation assembly (also called the bombing accelerometer) (Figure 4-5). The deflection assembly and the elevation assembly each include a gyro (Figure 4-6) with its associated stiffness motor and pickoff coils and armatures. The gyro is connected to the stiffness motor and pickoff armature shaft by means of a ball arm. The stiffness motor controls gyro sensitivity, or the magnitude of gyro response to airplane motion. It is also used for electrical caging. The pickoff transforms the precession motion of the gyro into an electrical signal. The stiffness motor and pickoff are electrically separate, but their armatures are mounted on a common shaft. Each assembly also includes a temperature control unit (Figure 4-7). A temperature-sensitive bulb and heater coil maintain the fluid in the armature shaft damper at a constant temperature. The superelevation assembly is known as the "bombing accelerometer" because it is used only when the sight is in the bombing function. It consists principally of a weight, lever arm, and two pneumatic bellows. The computer housing also contains two heaters and a temperature control to govern its internal temperature.

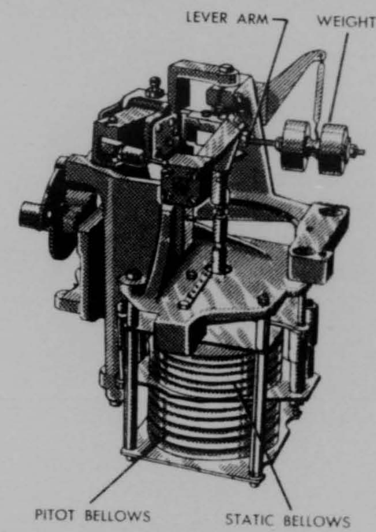

Figure 4–5. Superelevation Assembly (Bombing Accelerometer)

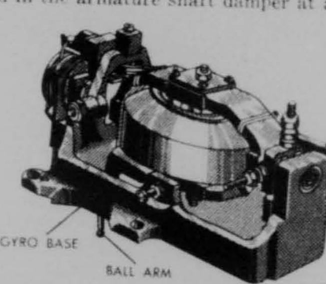

Figure 4–6. Elevation Gyro.

Connections to the computer are itemized in the following list. Not included in the list is the conventional shock mounting which secures the computer to the airplane. It is by means of this mounting that the airplane velocity and acceleration are transmitted to the two gyros and the bombing accelerometer, which use velocity and acceleration as data inputs.

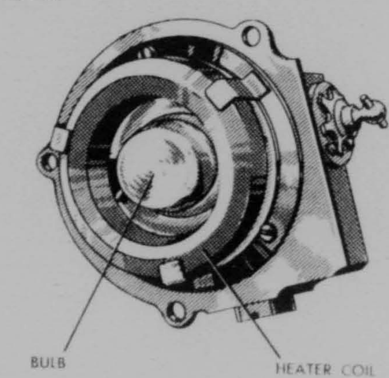

Figure 4–7. Temperature Control Unit.

Receptacle J102 (Figure 4-3), type AN-3102-28-16S, connects the computer with an electrical cable leading to the field test unit. This unit is not carried in the airplane and is used for test purposes only. It permits checking various signal voltages, gyro spin voltage, and temperature control heater voltage.

Receptacle P103 (Figure 4-3), type AN-3102-22-19P, connects the computer with an electrical cable leading to Jones socket S312 on the Amplifier. It carries excitation for the gyro pickoffs, stiffness motor current, gyro spin voltage, and supplies the temperature control units.

Receptacle J104 (Figure 4-3), type AN-3102-14S-5S, connects the computer with an

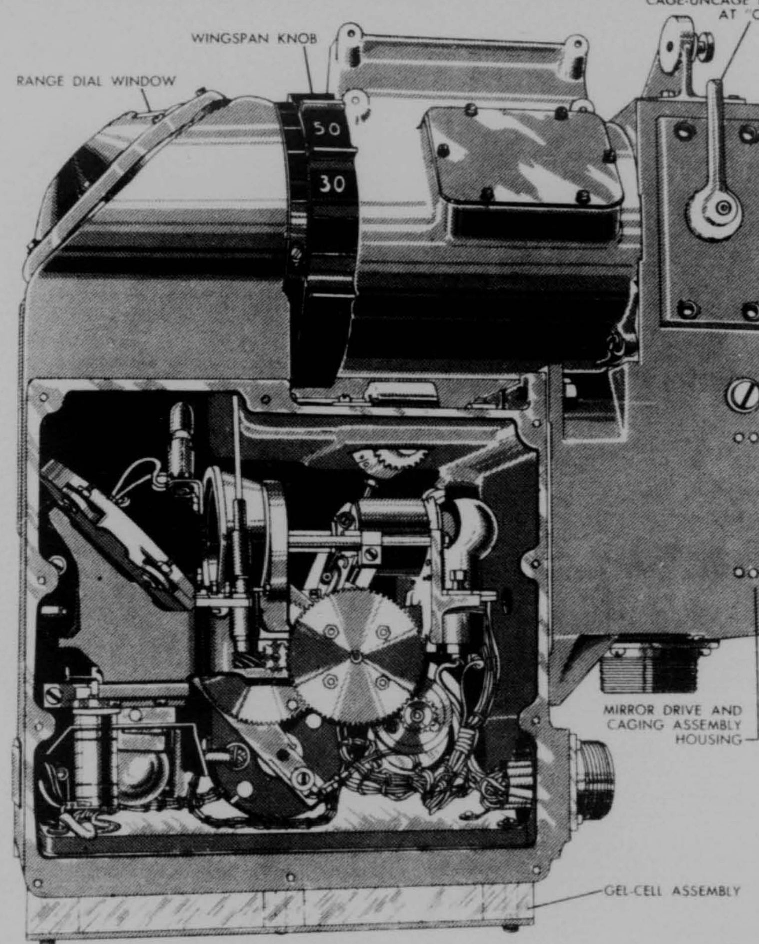

Figure 4—8. Sight Head, Rear Cover Removed.

electrical cable leading to Jones plug P306 on the amplifier. It carries the gyro pickoff signal voltages.

Connections (Figure 4-2) are provided for pneumatic tubes which supply static air pressure and pitot air pressure to the bombing accelerometer bellows.

A universal joint shaft connection (Figure 4-3) is provided for a shaft leading to the bomb-target wind unit. Rotation of the shaft, by the bomb-target wind knob, places the bombing accelerometer in the operating position (or swings it out of the operating position). At the same time, a switch is operated which controls three relays in the amplifier.

Sight Head. The sight head (Figures 4-8

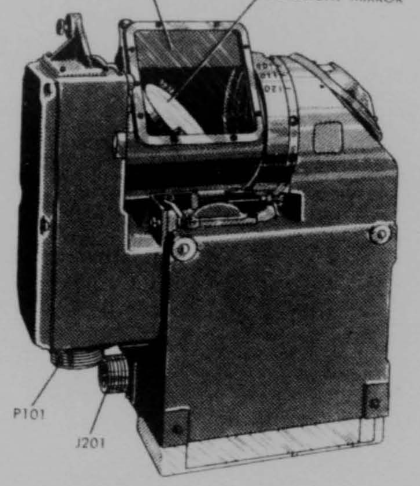

Figure 4—9. Sight Head, Front.

and 9) contains the optical system and associated electrical devices which position the reticle image. It is provided at the top with an inclined transparent window called the mirror shield. The light beam forming the reticle image is projected upward through the window to the airplane windshield. Therefore, the sight head is mounted with correct relation to the windshield. It is mounted also within the pilot's field of vision and within easy arm's reach, for it is provided with indicators and controls which must be adjusted prior to operation.

The principal components contained in the sight head are the elevation motor assembly, and the deflection motor and mirror assembly, which together comprise the essential units of the mirror drive and caging assembly. Also included in the sight head is the range-cone drive assembly. The elevation motor assembly (Figure 4-10) consists of a torque motor which is positioned mechanically by electrical signals, a pickoff which supplies a feedback signal, and a fluid damping unit. An armature shaft, common to motor and pickoff, terminates at one end in a lever, or ball arm. Motion of the ball arm positions the entire deflection motor and mirror drive assembly in elevation (Figure 4-11). This assembly consists of components which correspond to those of the elevation motor assembly, and the pivoted boresight mirror in addition. The ball arm on the armature of this assembly positions the mirror in deflection. Thus, the

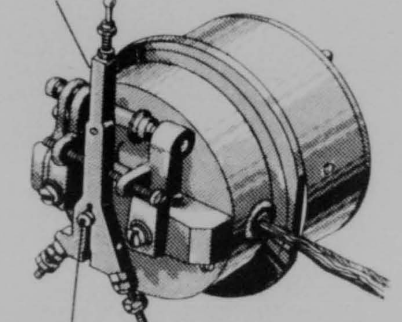

Figure 4—10. Elevation Motor Assembly.

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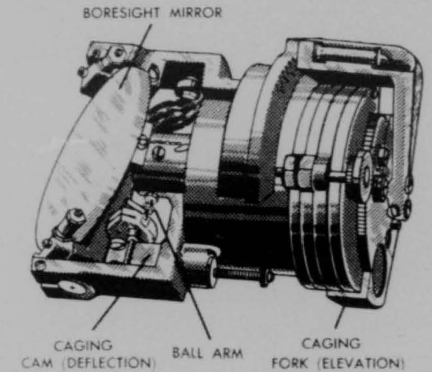

Figure 4—11. Deflection Motor.

mirror is positioned in elevation and deflection so that it reflects the reticle image upward to the windshield at the proper angle. This assembly also provides means for caging the mirror mechanically, or holding it stationary at the zero-prediction position. The range-cone drive assembly (Figure 4-12) consists of the light sources and components which provide the variable-size circle, the fixed-size circle, and the index dot for the reticle image. The variable-size circle is controlled in diameter by using a smaller or larger diameter of the cone to reflect a light beam from one light source. The fixed-size circle and index dot are formed by light from a second source as it passes through a fixed reticle. The two light beams are combined by a pellicle and other components of the optical system.

Connections to the sight head, and the indicators and controls provided, are described in the following list.

Wingspan knob (Figure 4-8). This large ring-shaped knob is mounted vertically with its indexed outer edge facing the pilot. It is used when the sight is operated with manual range instead of radar range. Then it must be set to the wingspan of the target, in feet.

"Cage-uncage" Lever (Figure 4-8). When this lever is at the "uncage" position the sight operates normally. When the lever is in the "cage" position the sight operates as a fixed-ring sight. The lever, in the "cage" position, actuates a fork and pin device which fixes the mirror in a zero-prediction position. The lever also actuates switches which remove operating power from the sight and provide a reticle circle image of fixed diameter.

Range Dial (Figure 4-8). This dial records the target range in hundreds of feet as determined by the ranging circuits, from either radar or manual range data.

Receptacle P101 (Figure 4-9), type AN-3102-PR-28-16P, connects the sight head with an electrical cable leading to Jones socket S318 on the Amplifier. It carries mirror pick-off excitation and signal voltages, torque motor current, and a 28-volt circuit controlled by the "cage-uncage" lever switch.

Receptacle J201 (Figure 4-9), type AN-3102-PR-22-14P, connects the sight head with an electrical cable leading to Jones socket S315 on the amplifier. It carries range data and energizing current for the bulbs which provide reticle image illuminations.

Amplifier

The amplifier (Figure 4-13) contains the electronic components of the sight, the air density unit (Figure 4-14) and six relays. It is shock-mounted, protected by an easily removable cover, and connected to other units by twelve electrical cables and the static pres-

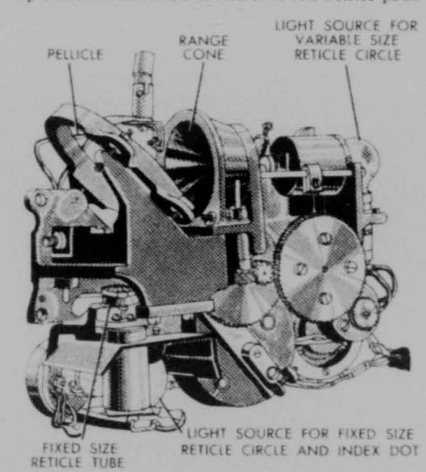

Figure 4—12. Range Cone Drive Assembly.

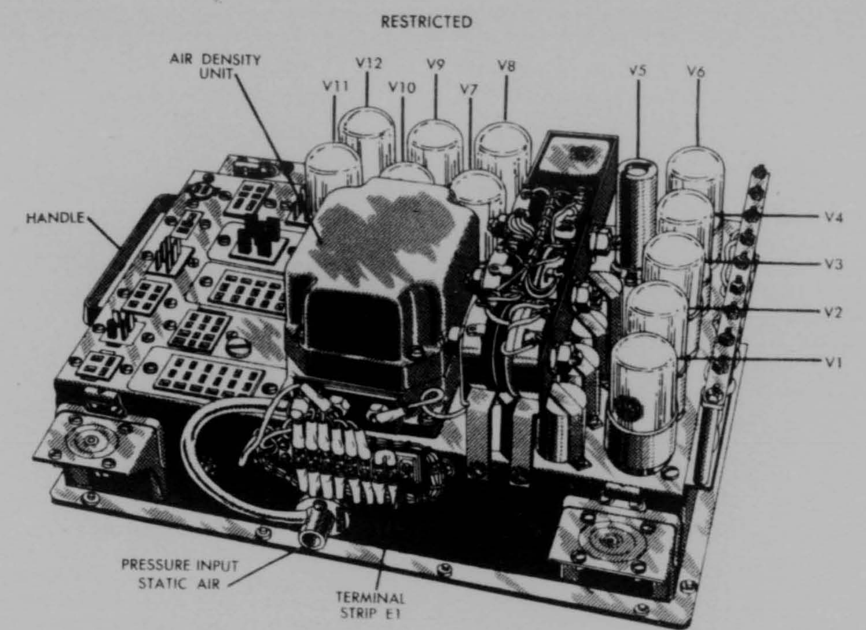

Figure 4—13. Amplifier.

sure tube. It is provided with a terminal strip, El, which is accessible after the cover is removed and which supplies convenient test points for the amplifier circuits. The amplifier may be divided functionally into four separate, but not independent, amplifier channels. These are the elevation channel (tubes V3 and V4), the deflection channel (tubes V1 and V2), the range channel (tubes V10, V11, and V12), and the sensitivity channel (tubes V5, V6, V7, V8, and V9). The three first named channels operate in the data circuits indicated by their names. The sensitivity channel supplies current to the stiffness motors in the computer. It thus limits the response of the gyros to airplane motion. The sensitivity channel operates from range data and air density data. Range data is supplied from radar or manual inputs. Air density data is supplied by the air density unit, which consists of a low-torque potentiometer with its arm linked and geared to an aneroid bellows, all mounted in a housing. The interior of the housing is maintained at static pressure and the bellows expands as altitude is increased.

The six relays are used to switch the sight from one function to another (gunfire, bombing or rocketfire), to energize the bomb release circuit in the airplane, and to cage the gyros electrically. The relays are operated automatically by the sight circuits, or by manually controlled switches located within reach of the pilot. The relays are described in the following list.

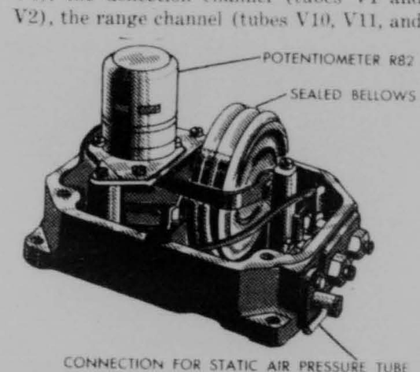

Figure 4—14. Density Unit Assembly.

Gun-bomb relay K2 is a double-armature relay but only one armature is used. It is energized when the bomb-target wind pointer is turned from "rocket-gun" to "bomb". When the relay is energized, the mirror in the sight head is positioned to give the fixed depression of the reticle necessary for bombing.

Gun-bomb relay K3 is identical with K2, but uses both armatures. It is energized in the same manner as relay K2. When energized, the sensitivity amplifier is disconnected and the elevation stiffness motor is pulled toward the lower elevation stop.

Gun-bomb relay K4 is identical with K2, but uses both armatures. It is energized in the same manner as K2. When it is energized, the output data of the elevation amplifier is used to operate the differential relay K1 instead of the mirror torque motors.

Differential relay K1 is a single armature relay with two energizing coils. It is energized by the output of the elevation amplifier (after relay K4 has been energized). When the current in one coil is the same as the current in the other coil, the relay is not energized. When the current is not the same in both coils, the relay becomes energized and, in turn, energizes relay K5.

Circle-bulb auto release relay K5 is identical with relay K2 but uses both armatures. It is energized by differential relay K1. When energized, it extinguishes the reticle image circle (but not the dot), and also completes a 28-volt circuit to the bomb-selector switch in the airplane. If the switch is at "auto" the bombs are then released.

Caging relay K6 is identical with relay K2 but uses both armatures. It is energized by the caging switch (airplane equipment) in the left grip of the airplane control stick. When energized, the gyros are caged electrically.

Connections to the amplifier are described in the following list. All electrical connections are made through Jones plugs or sockets mounted on top of the amplifier chassis (Figure 4-15). The connecting cables lead out and downward through the opening between the handle and the chassis. Some connections to the amplifier serve merely as convenient junctions for circuits between other units. For example, the circuit between the dimmer control and the reticle index dot-bulb in the sight head is completed through P304 and S315 in the amplifier.

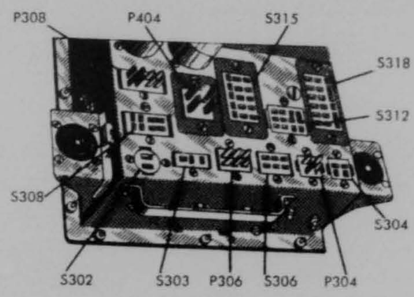

Figure 4—15. Amplifier Receptacles.

Socket S312 and plug P306 connect to cables leading to the computer, as previously described. Socket S315 and socket S318 connect to cables leading to the sight head, as previously described. Socket S315, in addition, provides an outlet for the 300 v fed to the manual range control.

Socket S302 connects with a cable leading to the electrical caging switch (airplane equipment) on the left grip of the control stick. The switch is used to cage the gyros electrically.

Socket S303 connects to a cable leading to the dynamotor, which is airplane equipment and located in the airplane power supply. The socket brings ±300 VC and ±28.5v DC into the amplifier.

Socket S304 connects to a cable leading to the phase adapter and three-phase transformer (115v to 29v), which are airplane equipment and located in the airplane power supply. The socket brings three-phase, 29-volt power to the amplifier.

Plug P304 connects to a cable leading to the dimmer control, which contains rheostats to adjust the intensity of reticle illumination.

Socket S306 connects to a cable leading to the bomb-selector switch and bomb-release relay (airplane equipment). The switch and relay are used when releasing bombs.

Plug P308 connects to a cable leading to the radar range unit. This connection brings both radar and manual range data to the amplifier.

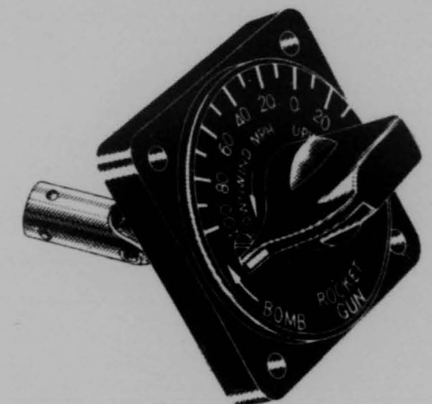

Figure 4—16. Bomb Target Wind Unit.

Socket S308 connects to a cable leading to the rocket-setting unit.

Plug P404 connects to a cable leading to the sight master switch and associated circuit breakers (airplane equipment).

Bomb Target Wind Unit

The bomb-target wind unit (Figure 4-16) consists of a rotatable pointer and fixed dial. It is mounted within reach of the pilot. The pointer is mounted on the outer end of a short shaft which projects inward through the dial and terminates in a universal joint. When the unit is installed, the universal joint is connected to a shaft leading to the computer. Rotation of the shaft places the superelevation assembly (bombing accelerometer) in operating position when the pointer is set at the "bomb" sector of the dial. In addition, a switch (S102) is closed which energizes gun-bomb relays K2, K3, and K4 in the amplifier. When the pointer is set at the "rocket-gun" position the bombing accelerometer is removed from operation and switch S102 is opened.

Radar-range Gear Box

The radar-range gear box (Figure 4-17) contains the components which receive the radar or manual range data from the radar

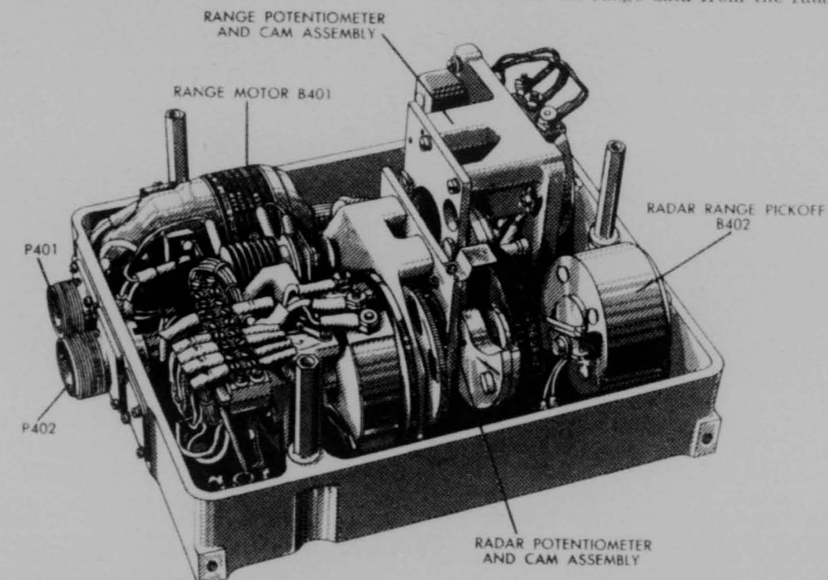

Figure 4—17. Radar-range Gear Box.

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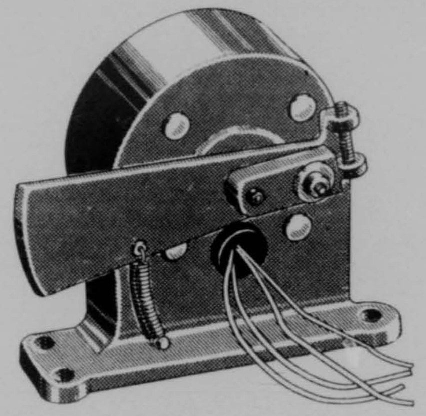


Figure 4—18. Radar-range Pickoff Assembly.

junction box J-271 APG-5C (airplane equipment) and which forward range data to other units of the sight. The principal components of the radar-range Gear box are the radar-range pickoff assembly, the range potentiometer and cam assembly, and the range motor. The radar-range pickoff assembly (Figure 4-18) is a signal source having a sector gear fixed to the armature shaft. The pickoff sector gear it driven by the range motor, through a gear train, pair of cams; and slip clutch on the radar potentiometer and cam assembly. The AC electrical data output of the pickoff is used to govern the size of the reticle image circle. The range potentiometer and cam assembly (Figure 4-19) consists of a potentiometer having its arm fixed to one of a pair of cams. The other cam is mounted on, and driven by, the same shaft that drives the pickoff sector gear. The DC electrical data output of the range potentiometer is used to control the sensitivity current in the gyro torque motors. The radar potentiometer and cam assembly (Figure 4-20) consists of a potentiometer having its arm driven by the range motor, through a gear and slip clutch. Also included are a range dial, and the pair of cams which drive the two assemblies previously mentioned. The DC electrical data output of the radar potentiometer is fed to the radar junction box J-271 APG-5C (airplane equipment). The range motor is a DC unit which is driven by electrical data from the radar junction box. The data rotates the motor to a position which is representative of target range. The motor is provided with limit switches and a rectifier network which prevent overtravel.

The radar-range gear box is provided with the indicator and connections described in the following list.

The range dial is visible through a window and is graduated in hundreds of feet from 600 feet to 6000 feet (Figure 4-17). The dial records target range.

Receptacle J401 (Figure 4-17), type AN-3102-16S-1P, connects with a cable leading to P308 on the amplifier. This connection carries the AC data output of the radar range pickoff and the DC data output of the range potentiometer.

Receptacle P401 (Figure 4-17), type AN-3102-18-1P, connects with a cable leading to the radar junction box (airplane equipment). It carries the output data of the radar potentiometer and brings to the unit the signals used to drive the range motor.

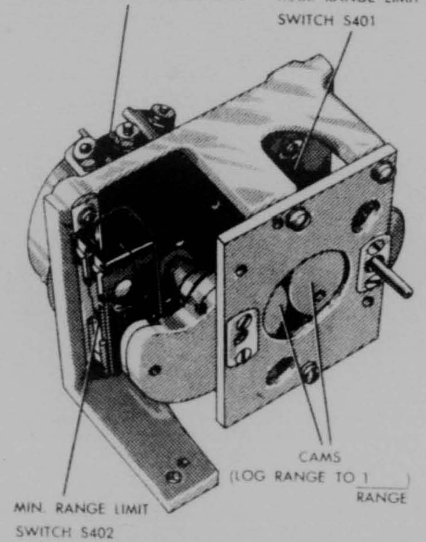


Figure 4—19. Range Potentiometer and Cam Assembly.

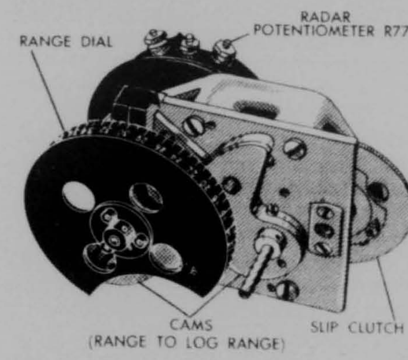


Figure 4—20. Radar Potentiometer and Cam Assembly.

Manual Range Control

The manual range control (Figure 4-21) contains the components which enable the pilot to insert range data into the sight manually. This is necessary when the associated radar set is not functioning. The control contains two switches and a potentiometer. These units govern components in the radar junction box (airplane equipment). The DC output data of the potentiometer, after the unit is set by the pilot, represents target range. The data is forwarded by the radar junction box to the radar range unit of the sight. In this unit the data performs the same functions as radar range data.

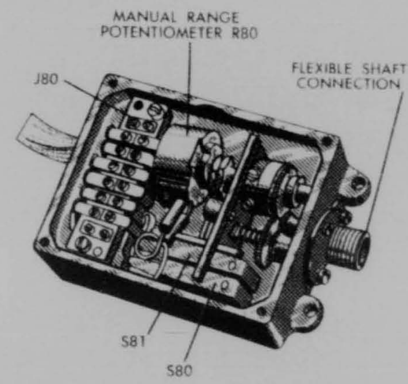


Figure 4—21. Manual Range Control.

The connections to the manual range control are described in the following list.

A flexible shaft is mechanically connected (Figure 4-21) to the potentiometer and switches, and leads to the airplane engine throttle control. This location is chosen for convenience of operation. The pilot, by rotating the throttle end of the flexible shaft, inserts range data into the sight.

The control is provided with an internal terminal strip (J80), (Figure 4-21), instead of an external receptacle. Connections to the terminal strip are led out through a hole in the housing, where they divide. Two leads, carrying the 300-volt supply for the potentiometer, are taken to S315 on the amplifier. The remaining leads, including one which carries the potentiometer pickoff voltage, are taken to the radar junction box (airplane equipment).

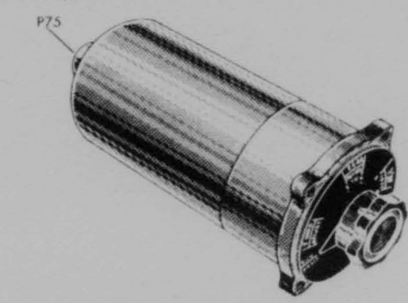


Figure 4—22. Rocket Setting Unit.

Rocket Setting

The rocket setting unit (Figure 4-22) contains the components used to adjust the sight for use in the rocket-fire function. It is mounted in the airplane within reach of the pilot. The principal components contained in the unit are a Selsyn-type signal source, a wafer switch, and three identical potentiometers. The signal source provides the signal which depresses the reticle image according to the type of rocket being used. The potentiometers provide a fixed sensitivity current for the gyro torque motors. The switch connects the signal source and potentiometers in the sight circuits or removes them from the circuits. The indica-

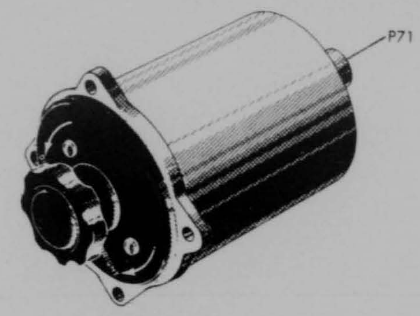


Figure 4—23. Dimmer Control.

tor and connection to the rocket-setting unit are described in the following list.

The rocket-setting pointer may be set at four positions. The "gun-bomb" position removes the rocket-setting unit from operation. The remaining three are used for rocketfire and connect the signal source and potentiometers in the sight circuits. The pointer shaft is connected directly to the wafer-switch arm and is connected by a gear and cam mechanism to the signal source. Each position of the pointer, except the "gun-bomb" position, provides a different reticle depression. Also, each of the three positions provides the fixed sensitivity current necessary for rocketfire.

Receptacle P75 (Figure 4-22), type AN-3102-18-8P, connects to a cable leading to S308 on the amplifier. It carries the output data of the signal source and the potentiometers.

Dimmer Control

The dimmer control, (Figure 4-23) contains the two rheostats which control the illumination intensity of the reticle image. One rheostat controls the variable-size reticle circle. The other controls the fixed-size reticle circle and the index dot for both reticle circles. Both rheostats are adjusted at the same time by the "dim-bright" knob. The dimmer control is provided with receptacle P71, type AN-3102-14S-2P, which connects with a cable leading to P304 in the amplifier.

3. INSTALLATION

General

The location of each of the eight components of the sight is determined by the function of the component, by the type of airplane in which the installation is being made, and by the length of the connecting cables. Four components (sight head, computer, amplifier and radar range) must all bear the same serial number, or an indication that all are part of the same sight. In addition, the sight head and computer must be installed in proper relationship to the airplane. Dimensions of each component are provided on the outline drawings in this section. As stated in this section no connecting cables, except the cable internally attached to the manual range control, are provided by the sight manufacturer.

When handling the computer it should be kept approximately upright. Do not allow it to remain tilted at more than 45 degrees for more than one minute at a time. Otherwise the damping fluid will tend to leak from the elevation and deflection assemblies.

The computer must be installed so that, when the airplane is in level flight, it will be correctly aligned.

The sight head must be located with the indicated points accessible for adjustment and so that two cables may be attached. It must be placed so that the wingspan knob and "cage-uncage" lever may be operated conveniently during flight. It must be located so that the plane of the four mounting pads is parallel to the windshield.

SECTION II—OPERATION

1. PRINCIPLES OF OPERATION

The motion of the airplane in which the sight is installed furnishes the principal data necessary for computation of the prediction angle. The data are derived from the precession of two gyros, one providing elevation (up-down) prediction and one providing deflection (left-right) prediction. The channel followed by elevation data from the gyro to the final purpose of positioning the reticle image on the pilot's windshield is similar to the deflection-data channel. For this reason, only the elevation channel will be discussed and the deflection channel differences pointed out in relation to it. Furthermore, it should be noted that the simplified schematics accompanying the text are not complete, and include only those components necessary for an understanding of the circuit. In addition to the data provided by the gyros, other input data are necessary for computation of the prediction angle. The additional inputs are range (from the radar range unit or the manual range control), air density, and indicated air speed.

2. THE FIRE CONTROL PROBLEM

The sight, which is the art of directing missiles so that hits are scored on selected targets. This problem is similar for bullets or shells, for bombs, and for rockets. The similarity depends upon the fact that each of these mis-

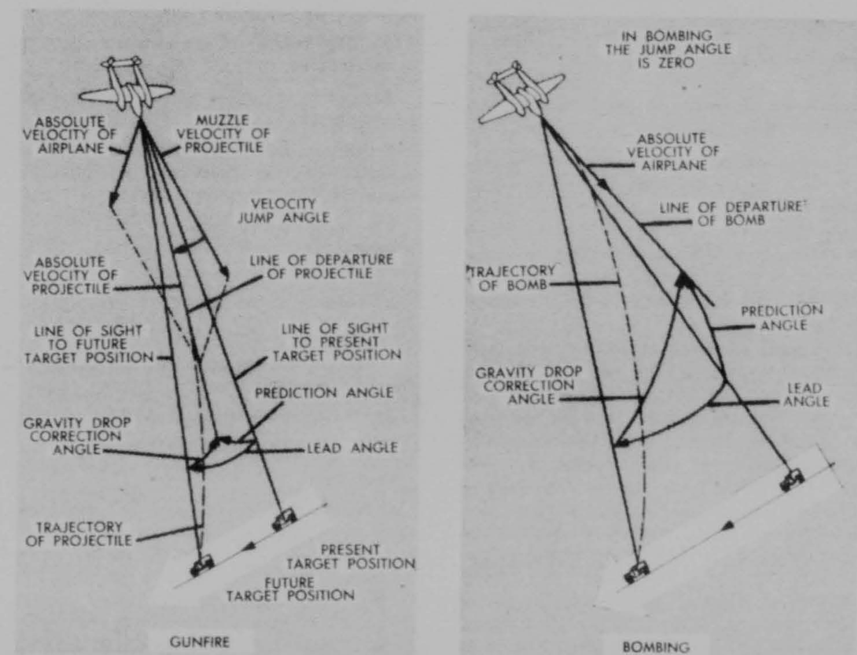


Figure 4—24. Gunfire and Bombing Against a Moving Ground Target.

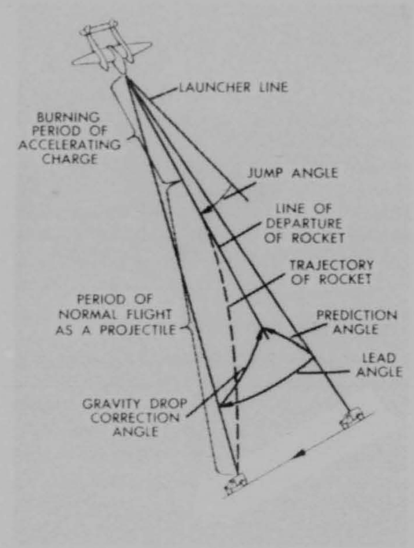


Figure 4–25. Rocketfire Against a Moving Ground Target.

siles ends its flight after a period of free motion under the laws of inertia and forces generated by motion through the air. A complete study of the aiming of projectiles is beyond the scope of this manual. A brief discussion is included, however, in order to aid an understanding of the operating principles on which the sight is based.

In order to score hits upon a moving target from a gun which is also moving, the gun must be aimed so that the proper angle, called the prediction angle, exists between the present line-of-sight to the target and the initial absolute velocity of the projectile. This velocity, for gunfire, is the resultant of airplane velocity and projectile muzzle velocity. For rocketfire, it is the resultant of airplane velocity and the launching velocity of the rocket. For bombing, the velocities of the airplane and bomb at time of release are the same. These relationships are indicated in Figures 4-24 and 4-25. This angular difference between airplane velocity and muzzle velocity (or launching velocity) is called the "jump".

The prediction angle is made up of the curvature correction angle and the lead angle (Figure 4-24). The curvature correction applied by the sight consists principally of the correction necessary for gravity drop. The lead angle is the angle between the line of sight to present target position and the line of sight to future target position. It is determined by range, projectile velocity, and the angular velocity of the line of sight as this line follows, or "tracks," the target.

3. GUNFIRE

The sight uses the following inputs for the control of gunfire:

Range (radar or manual).

Angular velocity of the airplane about the elevation axis (Figure 4-26).

Angular velocity of the airplane about the deflection axis (Figure 4-26).

Angular velocity of the airplane about the controlled line, or "roll" (Figure 4-26).

Atmospheric pressure (supplied by the density unit).

Resultant linear acceleration, including gravity, along the deflection axis (supplied by the gravity-drop accelerometer).

The sight uses the data inputs listed in the previous paragraph in order to make the following corrections, for gunfire:

a) Velocity of the target.

b) Velocity of the attacking airplane.

c) Rotation of the attacking airplane about the controlled line ("roll").

d) Gravity drop of the projectile.

e) Air density.

f) Range.

Corrections "a," "b," and "c" are based upon angular velocity data picked up by the gyroscopic elements from the motion of the airplane in which the sight is mounted. Correction "d" is based upon the linear acceleration of the airplane as picked up by the gravity drop accelerometer in combination with the dynamic behavior of the prediction mechanism itself. Correction "e" is based upon static

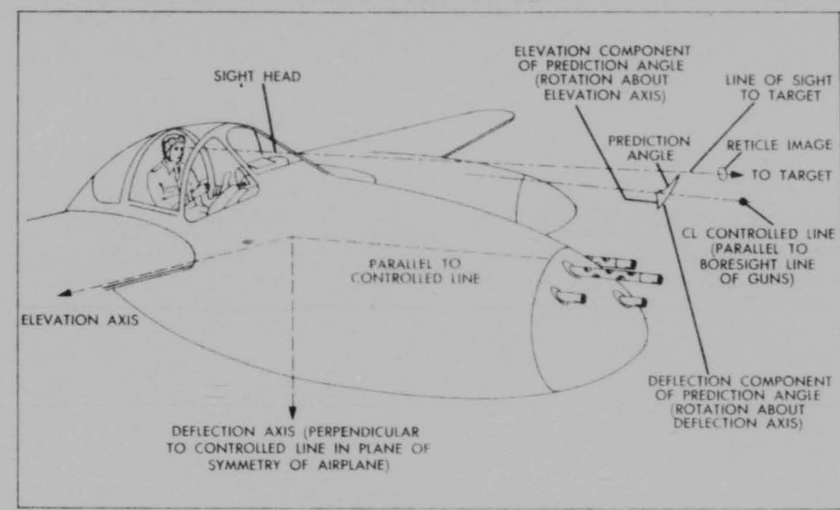


Figure 4–26. The Reference Axes of the Sight.

air pressure picked up by an aneroid bellows in the air density unit (not to be confused with the bellows in the bombing accelerometer). The calibration is based on the assumption that the actual pressure variation with altitude follows the standard pressure. Correction "f" is based upon range information, under the assumption that the airplane carrying the sight follows a proper pursuit curve against a target flying a straight line during an attack.

4. BOMBING

For bombing, the sight uses the following data inputs.

Angular velocity of the airplane about the elevation axis (Figure 4-26).

Angular velocity of the airplane about the deflection axis (Figure 4-26).

Linear acceleration along the deflection axis (supplied by the bombing accelerometer).

Component of gravitational acceleration along the deflection axis (supplied by the bombing accelerometer).

Indicated air speed (supplied by the bellows in the bombing accelerometer).

The sight uses the data inputs listed in the previous paragraph in order to make the following corrections, for bombing:

a) Gravity drop.

b) Target velocity.

c) Wind.

d) Air speed of bombing airplane.

e) Dive angle of bombing airplane.

f) Range.

g) Trail.

Trail, which may be defined briefly as the horizontal distance by which the bomb lags behind the airplane, is corrected, for an average bomb, by the calibration of the sight. Trail is caused by air resistance, or wind. The wind correction is complete only if the proper setting for the relative velocity of the wind with respect to the target is made on the bomb-target wind unit.

5. ROCKETFIRE

From the standpoint of fire control, rockets carried by aircraft and fired from "zero-length" launching rails are similar both to bombs and to projectiles fired from guns. They are similar to bombs in that they commence

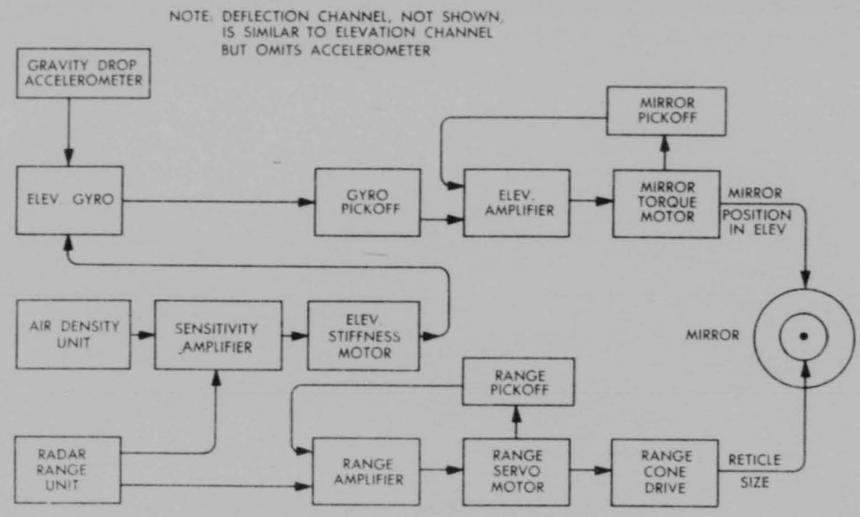


Figure 4–27. Gunfire, Simplified Block Diagram.

their independent flight with the same velocity as the airplane from which they are launched. After the rocket leaves the launching rails, a period of acceleration commences, which continues until the propelling charge has burned. During this period, the rocket may be considered as a projectile fired from an "equivalent gun" carried by the airplane. This imaginary weapon would have a long, curved barrel, shaped so as to give the projectile an absolute velocity identical in magnitude and direction with the actual velocity of the rocket at the end of the burning period. Following the burning period, the rocket behaves like a projectile fired from a stationary gun, with a muzzle velocity equal to the resultant of the airplane and propellant-produced velocities.

The sight uses the following data inputs for rocketfire:

Angular velocity of the airplane about the elevation axis (Figure 4-26).

Angular velocity of the airplane about the deflection axis (Figure 4-26).

Angular velocity of the airplane about the controlled line (Figure 4-26).

Linear acceleration along the deflection axis (supplied by the gravity drop accelerometer).

The sight uses the inputs listed in the previous paragraph in order to make the following corrections, for rocketfire:

a) Gravity drop.
b) Target velocity.
c) Wind velocity.
d) Air speed of the attacking airplane.
e) Range.
f) Dive angle of the attacking airplane.

6. ELEVATION PREDICTION

The elevation prediction system computes the elevation component of the prediction angle. This is the angle existing between the line of the gun barrel and the line of sight to the target when the gun is aimed so that a projectile will strike the target. The elevation prediction system receives its principal data input from the elevation gyro. Supplementary data inputs are range, atmospheric pressure, and linear acceleration (including gravity) along the deflection axis. The output of the system is represented by the elevation position of the mirror which reflects the reticle image to the pilot's windshield.

The block diagram of Figure 4-27 shows the flow of data through the sight when it is used for gunfire. Three data inputs are used, omitting the gravity drop accelerometer which is necessary in the elevation system only. The precession of the gyro provides mechanical motion which is a measure of the airplane's rate of rotation about the elevation axis. As shown in the diagram, the degree of precession is subject to an input that has its sources in the air density unit and the radar range unit. This input is discussed in the description of the sensitivity amplifier channel. Gyro precession is converted to an electrical signal by the gyro pickoff and sent through the amplifier and torque motor, which include a follow-up circuit. The torque motor positions the mirror by a mechanical linkage, and the position of the mirror is a measure of the prediction angle. The reticle image reflected by the mirror to the windshield furnishes the prediction angle to the pilot. The reticle image circle is controlled in size by the radar range unit, but if the radar range channel fails, the pilot must control the circle size manually. This is an emergency function and not included in the block diagram.

7. ELEVATION GYRO AND GRAVITY DROP ACCELEROMETER

The elevation gyro is a single-degree of freedom gyroscopic element, or "rate gyro". It differs from a free gyro in that the rotor has complete freedom of motion about one axis only. The gyro is mounted with its spin axis vertical, and the velocity of the airplane about the airplane's elevation axis causes the gyro to precess proportionately. This precession is the data output of the gyro. Precession is controlled by the elastic restraint of the stiffness motors, which are described as a portion of the sensitivity channel. Maximum precession is limited by mechanical stops.

The elevation gyro exhibits the usual gyroscopic properties of rigidity and precession. Rigidity resists any change in the gyro's plane of rotation. Precession results when the gyro's plane of rotation is forcibly changed. If this plane is changed by a torque applied about

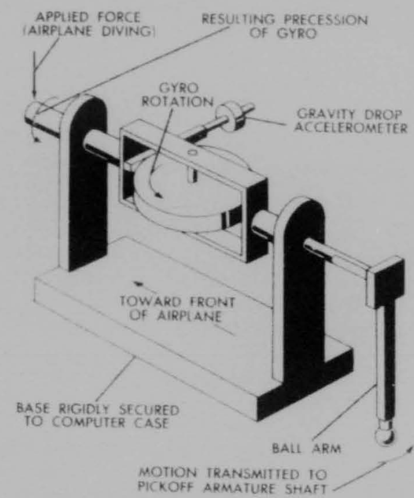


Figure 4–28. Elevation Gyro and Gravity Drop Accelerometer, Simplified Schematic.

either of the two nonspin axis of a gyroscope, the spin axis will rotate (precess) in a direction which tends to make its vector coincide with the applied torque vector. Precession resulting from diving motion of the airplane is illustrated in Figure 4-28. This figure also illustrates the method by which the precession movement is transmitted to the gyro pickoff.

The gravity drop accelerometer (Figure 4-28) inserts into the elevation system an angular correction for gravity drop of the projectile. This angle is one of the effects that must be taken into account by all fire control equipment. In aerial gunnery, the angle is so small that it differs a negligible amount from its own sine. It is maximum when the guns are aimed in the horizontal plane and is zero when the guns are pointing straight up (or down). The weight of the accelerometer tends to cause gyro precession in a direction which will depress the reticle image (elevate the guns).

8. ELEVATION GYRO PICKOFF

The elevation gyro pickoff converts into an electrical signal the precession of the gyro, in

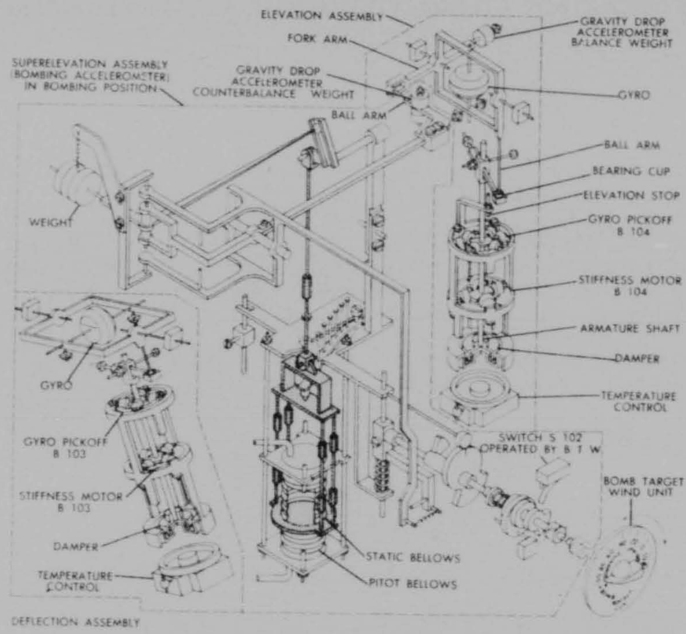
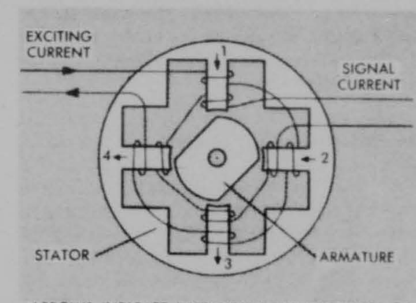


Figure 4–29. Mechanical Schematic, Computer

both magnitude and direction. When the gyro precesses it moves the ball arm (Figure 4-28). The ball on the lower end of the arm engages a bearing cup which serves as a socket for the ball. The cup is fixed to the armature shaft which carries the pickoff armature and the stiffness motor armature. The relationship between cup and shaft is that of a crank to a crankshaft. Unlike the usual crankshaft, however, the rotation of the armature shaft is limited by mechanical stops. Movement of the shaft turns the armature. Neither of the armatures are connected to any electrical source and each, with its stator winding, is a separate electrical component. The shaft, both armatures, and both sets of coils are contained in one unit called the elevation stiffness motor assembly and designated electrically as B103 (Figure 4-29).

The gyro pickoff coils are wound on a laminated stator having four coils spaced 90 mechanical degrees apart. Each coil has electrically isolated windings. The windings are connected in two series groups, each group composed of corresponding coil windings. The operation of the pickoff depends in part upon the direction in which the coils are wound. This direction is shown in Figure 4-30, as is the instantaneous direction of the exciting current flowing through them. The right-hand rule gives the direction of magnetic flux in each pole, which is indicated by the heavy arrows. The amount of the flux depends upon the position of the armature. When the armature is in the position shown, all air gaps are equal and the flux is the same in all poles. When the armature is rotated through a small angle clockwise, the overlap at poles 2 and 4 is greater than at poles 1 and 3, and the flux is correspondingly greater. This flux variation, over the range of motion allowed by mechanical stops, is a linear function of the armature angle from the equal flux position.

The signal current windings are cut by the flux which results from the exciting current and current is induced in them by trans-



ARROWS INDICATE INSTANTANEOUS DIRECTION OF MAGNETIC FLUX IN POLES, CAUSED BY 400-CYCLE EXCITING CURRENT

Figure 4—30. Pickoff, Simplified Schematic.

former action. Figure 4-30 shows that the signal winding direction at pole 1 is opposite to the direction at pole 2. Therefore, since the flux in both poles is in the same direction (from stator toward armature), the resulting voltage in these windings will be opposite in sign. When the armature is in the position shown, the voltage in signal windings at pole 1 and 2 will cancel each other. The same reasoning applies to the windings at poles 3 and 4. Thus the signal windings produce no output. However, when the armature is rotated through a small angle clockwise, the flux in poles 2 and 4 increases and the flux in poles 1 and 3 decreases. The flux in pole 1 aids the flux in pole 3, and the flux in pole 2 aids the flux in pole 4 because, between the two members of each pair, there is a reversal of both flux direction and signal winding direction. Thus the signal output is the amount by which the voltage across the windings at poles 2 and 4 is greater than the voltage at poles 1 and 3. The magnitude of the voltage is a linear function of the angular displacement of the armature. When the armature is rotated in the opposite direction (counter-clockwise), the voltage across poles 1 and 3 will be greater than the voltage across poles 2 and 4. Also, the 1-3 voltage is opposite in sign to the pole 2-4 voltage. Therefore, the output voltage will be opposite in sign to the output voltage for clockwise rotation of the armature. The opposite sign, for an instantaneous value, means that the phase has reversed.

The previous paragraphs have demon-

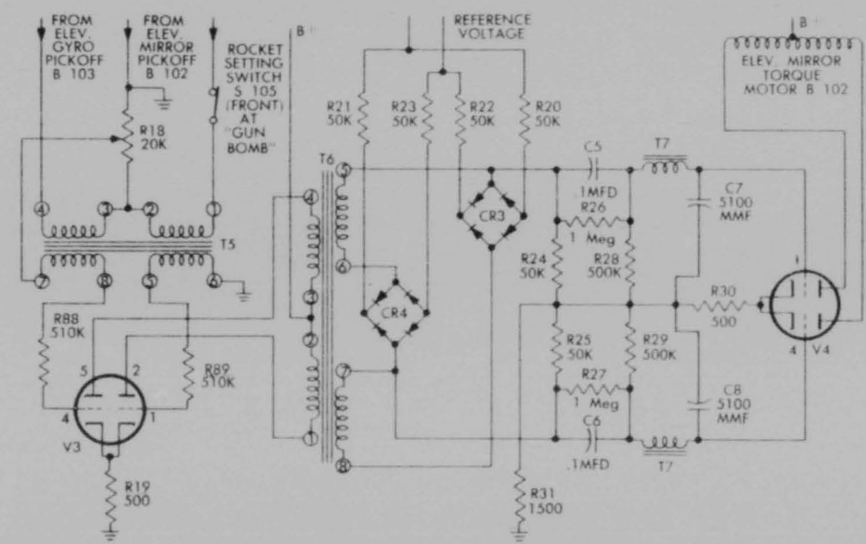


Figure 4—31. Elevation Amplifier, Simplified Schematic.

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strated that, for every angular position of the armature, the pickoff produces a signal voltage of corresponding magnitude. Further, the phase of the voltage depends upon the direction of rotation of the armature from the "no-signal" position. The output of the elevation gyro pickoff is applied to the elevation amplifier channel. In addition to the signal, the amplifier receives a feedback signal representing the elevation position of the mirror. This signal is developed in the elevation mirror pickoff B102, which is electrically identical with the gyro pickoff.

9. ELEVATION AMPLIFIER

The elevation amplifier (Figure 4-31) consists of tubes V3 and V4, together with associated components, and is located in the amplifier unit. Its purpose is to create a signal which drives the elevation-mirror torque motor B102 into correspondence with the elevation gyro pickoff on the armature shaft of B103. The armature of the elevation torque motor is connected mechanically with the mirror. When the gyro pickoff and mirror torque motor are in electrical alignment, the mirror is in the position directed by the gyro.

It should be observed that when the torque motor and mirror are not in alignment, the error must be identified to the amplifier in direction as well as amount. The direction of the error is indicated by the phase of the error signal, for the pickoff is phase sensitive and is excited by the same source as a reference transformer in the amplifier. The following discussion, for simplicity, assumes an error of one direction only, but is equally applicable to an opposite error. The combined signal input to the elevation channel is developed in the center-tapped primary of transformer T5 (Figure 4-31). Winding 3-4 receives signals from elevation gyro pickoff B103 which represent the position of the gyro. Winding 1-2 receives signals from elevation mirror pickoff B102 which represent the position of the mirror. (Note that mirror pickoff B102 is electrically separate from mirror torque motor B102). The algebraic sum of these two voltages is the elevation-channel input. The amplitude of the input measures the magnitude of the difference in position between the elevation gyro and the mirror. The phase of the input, with reference to the exciting voltage of the pickoffs, indicates the direction of the position difference.

A portion of the input voltage, taken from the center tap of the primary winding, is applied in series with secondary winding 7-8. This circuit applies a compensating voltage to grid 4 of V3. The voltage may be changed by means of potentiometer R18, permitting adjustment for any difference in sensitivity between the gyro pickoff and the mirror pickoff.

The elevation channel input voltage induces corresponding voltages in both secondaries of T5. Assuming that, at the instant under discussion, these AC voltages are positive at terminals 5 and 7: These voltages are applied to both grids of amplifier V3 through the grid current limiting resistors R88 and R89. This tube normally is conducting. The grid signals cause the voltage at plate 5 to rise and the voltage at plate 2 to fall. The change in plate current is coupled through transformer T6. The secondary voltages at T6 would be positive at terminals 5 and 7 for the original condition assumed.

The output of the transformer T6 secondary windings is applied to the selenium rectifier networks CR3 and CR4. These networks rectify the AC output of transformer T6, permitting current to flow through the circuit of only one winding at a time. Winding 7-8 of transformer T6 forms a series circuit with rectifier network CR3 and load resistors R24 and R25. Winding 5-6 is in series with CR5 and the same load resistors. The conducting condition of the networks, however, is not determined by the comparatively low signal voltage from transformer T6 but instead is determined by the 100-volt reference voltage from transformer T4 (not shown in Figure 4-31). The transformer is protected by resistors R20, R21, R22, and R23 in the event that the rectifier networks become shorted. The reference voltage is in phase with the excitation voltage supplied to both the gyro pickoff B103 and the mirror pickoff B102. Connection between reference transformer T4 and the rectifier networks CR3 and CR4 are such that each network conducts on alternate half-cycles of the reference voltage. For example, during

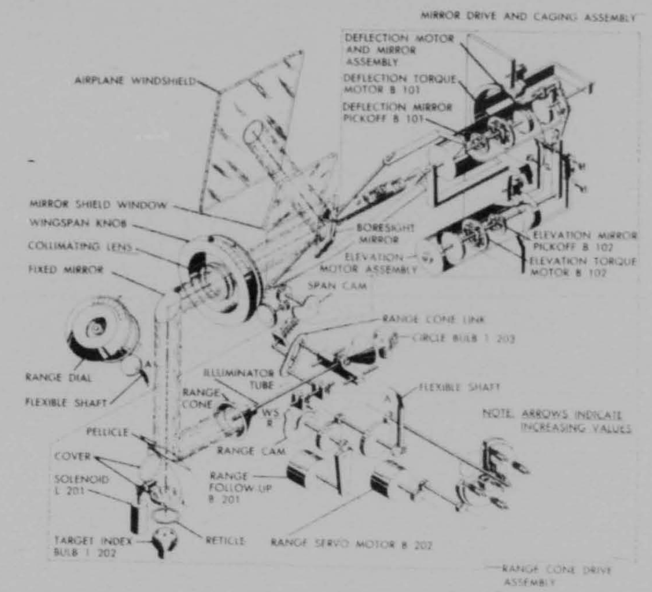

Figure 4—32. Mechanical Schematic, Sight Head

the half-cycle when the network terminals at R22 and R23 are positive (at this instant terminal 5 on Ty is also positive), CR3 is cut off and CR4 is conducting. For this condition of the rectifiers, winding 7-8 on T6 is open-circuited by network CR3. Current flows from winding 5-6 through load resistors R24 and R25 through one leg of CR4 to R21 and the winding of the reference transformer, returning through R23 and another leg of CR4 to winding 5-6. In the conventional sense, the flow is from top to bottom through the load resistors because terminal 5 on T6 was found to be positive.

During the half-cycle of reference voltage when the network terminals at R22 and R23 are both negative, CR3 conducts and CR4 is cut off. Winding 5-6 is open-circuited while winding 7-8 conducts. Also, because the pickoff exciting voltages and the reference voltage are in phase, terminals 6 and 8 on T6 become positive (instead of 5 and 7). Current flows through CR3 and again from top to bottom through R24 and R25. In this manner the AC output of V3 is converted to a DC signal.

The DC voltage, at the upper end of resistor R24 charges capacitor C5. The other side of this capacitor is grounded through R28 and R31. This RC circuit may be looked upon as a differentiating circuit which "peaks" the voltage signal. Thus, variations in the level of the DC will be effective immediately when applied to the torque motor which moves the mirror. After "peaking", the voltage signal is applied to inductor T7 and capacitor C7. These components reject any remaining 400-cycle fluctuations. Then the signal is fed to grid 1 of V4, which serves as a power amplifier. Grid 4 of V4 receives signals in a similar manner. They are developed at the opposite end of the two load resistors, however, and are always opposite in instantaneous polarity to the grid 1 signals.

The plate supply of the tube is applied through the center tap of the elevation torque motor B102 stator winding. The tube normally is conducting, so that the same amount of plate current flows in each half of the tube and also in each half of the torque motor winding. Any signal voltage on the grids of the tube disturbs the equality of the current flow in the halves of the motor windings and causes the motor to rotate. The direction of rotation depends upon the relative polarity of the grid signals, which in turn depends upon the direction of misalignment between the gyro pickoff and the mirror pickoff. The motor continues to rotate until the misalignment is cancelled and the mirror is in the position directed by the gyro.

An error of one direction (between gyro pickoff and mirror pickoff) was discussed in the preceding paragraphs. This error made terminals 5 and 7 on input transformer T5 positive at the instant when the reference voltage causes the rectifier networks to be positive at their junction with R22 and R23. Now assume that the error between gyro pickoff and mirror pickoff is in the opposite direction. Then the phase of the error voltage, with respect to the reference voltage, will change by 180 degrees, in other words, terminals 6 and 8 on T5 will be positive when the networks are positive at R22 and R23. Then current flows from winding 5-6 through one leg of CR4, R21, the winding of the reference transformer, R23, another leg of CR4, and upward through the load resistors R25 and R24. On the next half-cycle of both reference voltage and error voltage, current flows from winding 7-8 on T6 and again upward through R25 and R24. Thus an error of opposite direction produces a reversal of current through the load resistors. The reversed current, applied to output tube V4, in turn causes the torque motor to rotate in the opposite direction.

10. ELEVATION TORQUE MOTOR

The elevation torque motor armature (Figure 4-32) is mounted on the same shaft as the armature of the elevation pickoff. The shaft is connected mechanically to the mirror. Although the motor and pickoff are both part of the same unit mechanically, and are designated by the same electrical symbol B102, there is no direct electrical connection between them. The pickoff, as previously described, furnishes a signal to the amplifier representing mirror position. The torque motor drives the armature shaft, and thus the mirror, in a direction and to a position that will cancel the pickoff signal.

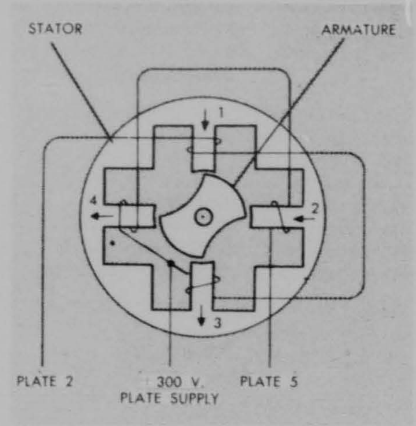

Figure 4—33. Torque Motor, Simplified Schematic.

The torque motor is somewhat similar to the pickoff, as may be seen by comparing Figures 4-30 and 4-33. The four poles of the torque motor, however, have identical single windings. These windings receive the output signal from the plates of tube V4 in the elevation amplifier channel (Figure 4-31). The conventional current in a vacuum tube is always the same, from plate supply through plate load to plate, and thence to cathode. This current in tube V4 is steady and is the same for each plate when no elevation signal exists. The current will create magnetic flux in the poles of the torque motor. The direction of the flux is shown by the heavy arrows in Figure 4-32. The flux in pole 1 has the same magnitude as the flux in pole 3, regardless of armature position, because the air gaps at these poles are always equal. For the same reason, the flux in pole 2 is of the same magnitude as the flux at pole 4. However, when an elevation signal does exist, the plate current in one half of tube V4 is not the same as the plate current in the other half. Then current around poles 1 and 3 is not the same as the current around poles 2 and 4. This difference creates the

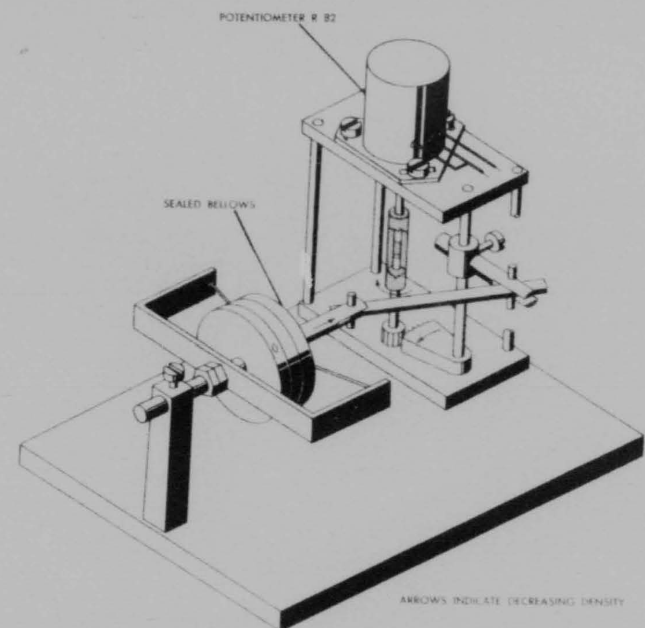

Figure 4—34. Mechanical Schematic, Density Unit.

torque which rotates the torque motor armature. When the torque motor armature rotates, the elevation mirror pickoff armature is rotated also because it is on the same shaft. The rotation is in the direction to drive the pickoff into electrical agreement with the gyro pickoff. When this agreement occurs, the input to the elevation amplifier channel becomes zero and the torque motor ceases to rotate. The mirror is then in the correct position for reflection of the reticle image at the correct elevation prediction angle.

11. AIR DENSITY UNIT

The mirror position in elevation, although determined principally by airplane motion as interpreted by the elevation gyro, is also subject to two additional sources of data (Figure 4-27). The air density unit is one of these. The unit receives barometric pressure and uses this information to partially control the DC input to the sensitivity amplifier.

Barometric pressure, at the plane's altitude, is used as a measure of air density. The aneroid bellows in the unit expands with decreased pressure. This motion, through a linkage and sector gear, rotates the arm of potentiometer R82 (Figure 4-34). This potentiometer is connected in the input circuit of the sensitivity amplifier as shown in Figure 4-35.

12. RADAR RANGE GEAR BOX

The remaining data input controlling the mirror position in elevation is derived from target range. This information is received by the radar-range gear box, from the APG-5 radar set, through the radar junction box. The radar-range gear box contains a motor which is driven by the target range data. The motor is connected to the rotor of a pickoff and also to the arm of the range potentiometer (Figure 4-36). The pickoff furnishes an AC signal to

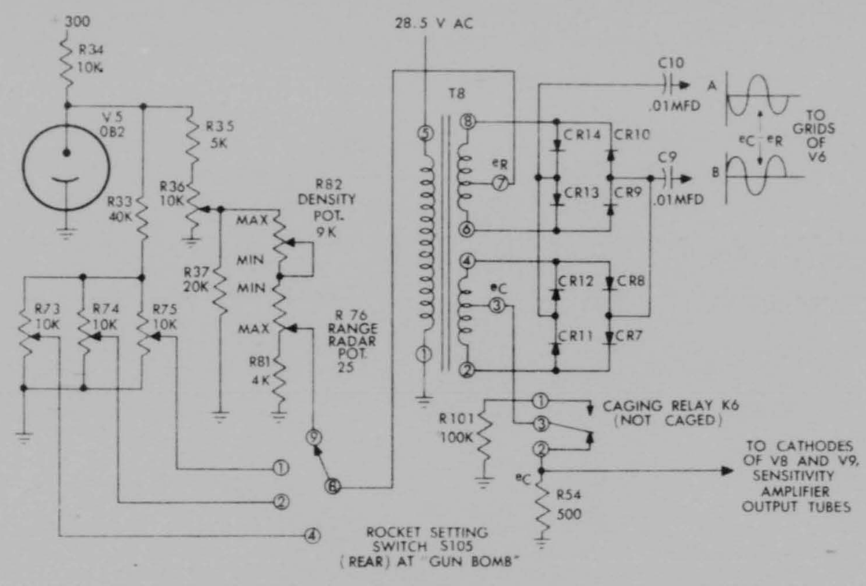

Figure 4—35. Sensitivity Amplifier Input Circuit, Simplified Schematic.

the range servo motor, in the sight head, which controls the size of the reticle image circle. This signal does not affect mirror position. The range potentiometer, however, furnishes a DC signal which is used as an input to the sensitivity amplifier. It is designated as R76 and is connected in the amplifier input circuit as shown in Figure 4-35. Range data is necessary in order to compute the prediction angle correctly. This necessity is evident when it is considered that a distant target flying at high speed will cause the same tracking rate as a nearby target flying at a correspondingly low speed. The required prediction angle for the distant target will be greater than the prediction angle for the target at the lesser range.

13. SENSITIVITY AMPLIFIER

The sensitivity amplifier consists of tubes V5, V6, V7, V8, and V9, together with associated components, and is located in the amplifier unit. Its purpose is to impose an elastic restraint upon the precession of the elevation and deflection gyros. The restraint is applied to the pickoff armature shaft of each gyro, through the stiffness motors, as an electrical torque. The magnitude of the torque is determined by the range of the target and by air density (Figure 4-27). The torque is used also to cage the gyros electrically. For this purpose sensitivity signals are applied to the stiffness motors at maximum value, because data signals are cut off.

When the sensitivity amplifier is functioning normally, the air density and radar range data are combined and applied to it as a DC signal. Tube V5, a voltage regulator, maintains a constant 105 volts between the upper end of R35 and ground (Figure 4-35). The density potentiometer R82 and the radar range potentiometer R76 are series connected, and pick off a portion of this voltage drop. This DC voltage (e_R) is the sensitivity amplifier input. It is applied to terminal 7 of input transformer T8 through rocket setting switch S105. A feedback voltage (e_c), developed by the flow of current through cathode resistor R54, is

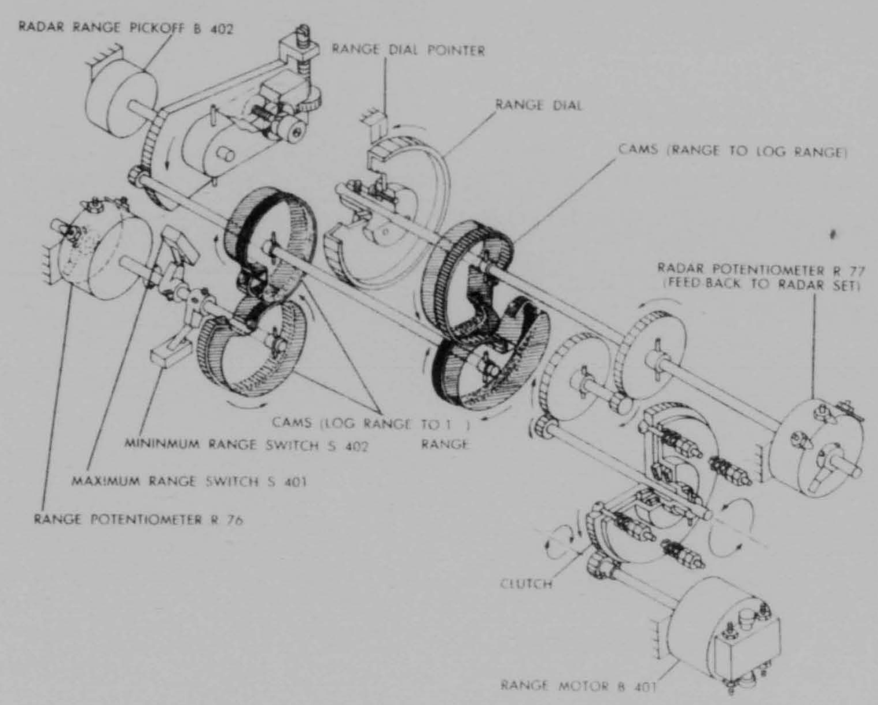

Figure 4—36. Mechanical Schematic, Radar Range Gear Box.

also applied to transformer T8, at terminal 3. The difference between these DC voltages ($e_R—e_c$) is alternately switched from lead A to lead B by the action of the AC reference voltage on the bridge-rectifier circuit. The voltage on leads A and B will then appear as shown in Figure 4-35. Capacitors C9 and C10 remove the DC level, resulting in AC signals being applied to the grids of V6. These signals will be 180 degrees different in phase, and their magnitude (which will be equal) will be determined by the difference ($e_R—e_c$).

The push-pull input to V6 is amplified by V6 and V7, with the primary of transformer T9 in the plate circuit of V7. The secondary of T9 is applied to a reference voltage-rectifier network similar to the equivalent network in the elevation amplifier. This network feeds a negative signal to the grids of output tubes V8 and V9 (Figure 4-37). The tubes receive their plate supply through one end of the series-connected stiffness motors V103 and B104. With no signal on the grids these tubes are conducting normally and current through the stiffness motors is maximum. This condition occurs when the DC sensitivity input is maximum (for minimum range). When the grids of V8 and V9 receive a negative signal the stiffness current decreases. This is the condition for increasing range.

When a heavy current is being drawn through V8 and V9 (minimum range) the voltage drop across R54 (e_c) will be high. At the same time, the range input voltage (e_R) will also be a maximum, and the net difference of the two will be fairly small. This will cause

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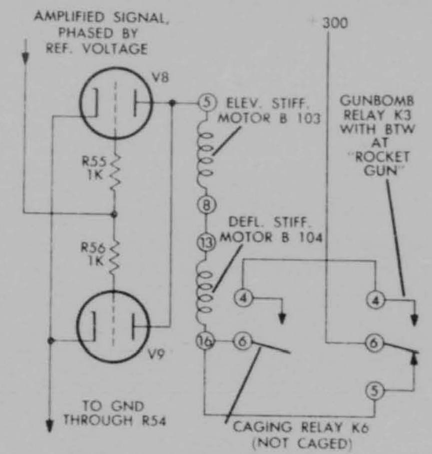

Figure 4—37. Sensitivity Amplifier Output Circuit, Simplified Schematic

a very low voltage signal ($e_R - e_C$) to be applied to the amplifier tubes (V6 and V7) and therefore there will be a small negative bias on the grids of V8 and V9, maintaining a heavy current flow. If the range voltage is decreased (increasing range) the difference ($e_R - e_C$) will increase, causing a larger negative signal to be put on the grids. This will cause the current flow to decrease appreciably reducing the torque of the stiffness motor B103. Multistage degenerative feedback is obtained in this amplifier channel by virtue of the fact that cathode resistor R54 is connected in series with the range potentiometer arm from which the input voltage e_R is obtained. The feedback factor is such that optimum linearity is obtained in the sensitivity channel.

14. ELEVATION STIFFNESS MOTOR

The elevation stiffness motor (Figure 4-29) is a part of the assembly which includes the elevation gyro pickoff. The deflection stiffness motor is correspondingly mounted. Both motors are similar electrically and this discussion of the elevation stiffness motor applies to the deflection stiffness motor as well. The armature of the motor is mounted on the same shaft as the armature of the gyro pickoff. When the gyro precesses, its precession is partially restrained by the torque caused by the current in the stiffness motor windings. This current is the sensitivity current. It affects the gyro directly, as indicated in the block diagram (Figure 4-26). If there is no sensitivity current, the stiffness motor has no effect on gyro precession. If the current is the greatest allowed by range and density data, gyro restraint is greatest. The stiffness motor is used also for electrical caging. For this purpose, range and density data are removed from the sensitivity channel input. The stiffness motor then receives a steady maximum current through its windings and holds the armature firmly in "neutral" position. This action cages the gyro.

A simplified schematic of a stiffness motor is given in (Figure 4-38). With the armature in the position shown, the air gap reluctances are the same at all poles. If the armature is turned slightly clockwise, the reluctance at poles 1 and 3 increases, while at poles 2 and 4 it decreases. Thus more flux will flow from the armature into poles 2 and 4 than from poles 1 and 3 into the armature. But the net inflow to the armature must be zero. Therefore some of

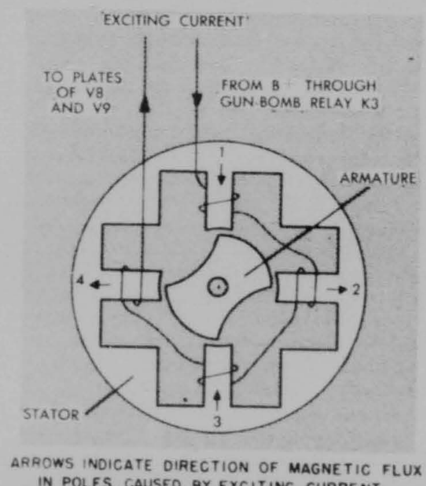

Figure 4—38. Stiffness Motor, Simplified Schematic.

the magneto-motive force at poles 2 and 4 is transferred to poles 1 and 3, and the flux density at 1 and 3 is increased. Thus, the counterclockwise torque of poles 1 and 3 exceeds the clockwise torque of poles 2 and 4, and creates the restoring effect of a spring. The effect is proportional to the square of the flux density and, therefore, of the current. The same effect is present for counterclockwise rotation, with torque at poles 2 and 4 predominating in this case. Over a useful range the torque is practically linear with angular displacement.

15. MIRROR DRIVE LINKAGE FOR ELEVATION

The elevation torque motor, as well as the elevation mirror pickoff, is housed in the elevation motor assembly (Figure 4-32). The armatures of both the torque motor and the pickoff are mounted on the same shaft. One end of the shaft extends from the elevation motor housing, and carries a ball arm on its outer end. The ball arm is mounted at right angles to the shaft. When the shaft is rotated by the torque motor, the ball on the end of the ball arm moves through a corresponding arc. Motion is limited by the elevation stop mounted on the end of the housing. The ball arm projects upward from the elevation motor housing and the ball engages a fork on the deflection motor and mirror assembly. The fork is attached rigidly to the rotating housing which supports the mirror. The mirror rotates in elevation when the fork is moved by the ball arm.

16. ELECTRICAL CAGING

The sight employs electrical caging to prevent precession of the gyros before the pilot begins to track a target. If this provision were not made, the maneuvering of the plane during the pilot's initial approach to a target would insert spurious rates into the sight. In order to cage the gyros electrically the pilot depresses the push button type of caging switch on the left grip of the plane's control wheel. This switch energizes caging relay K6. When the caging relay is energized, all data inputs are removed from the sensitivity amplifier. Relay contacts 2-3 open and 3-1 close (Figure 4-35). This action places a high value resistor in series with the range and density data inputs to the amplifier and effectively cuts them off. It also removes the voltage e_C, so that there is no difference signal ($e_R - e_C$) = 0, this results in cutting off the grid bias on V8 and V9, which therefore draw maximum current. Maximum current through the stiffness motor windings holds the stiffness motor armatures in a fixed position. As each armature shaft is mechanically connected to the gimbal of the corresponding gyro, movement of the gimbal is prevented. When the gyros are caged, the signals created by the gyro pickoffs hold the mirror in a fixed position.

The previous paragraph described the action of one of the two sets of contacts on caging relay K6. The other set does not affect the sight in the gunfire function. As shown in Figure 4-37, however, the plate supply to the sensitivity amplifier is cut off by gun-bomb relay K3 when this relay is in "bomb" position. Therefore, when the sight is in the bombing function, contacts 4-6 on caging relay K6 are used to close the circuit which has been opened by gun-bomb relay K3. Thus electrical caging is effective for both gunfire and bombing functions.

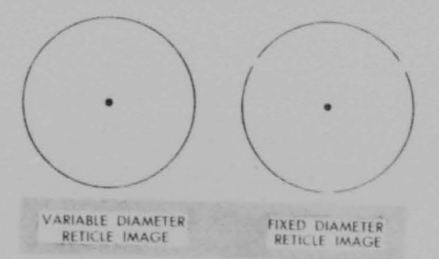

Figure 4—39. Reticle Image.

17. MECHANICAL CAGING

Mechanical caging is used when the sight is to function as a fixed sight. Under this condition a fixed reticle image (Figure 4-39) is projected on the pilot's windshield and no prediction angle is indicated. The sight may be caged mechanically by means of the "Cage-Uncage" lever located on the sight head. This

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lever, when in the "Cage" position, will engage a pin with a fork that is fixed to the elevation armature shaft, and hold the shaft steady. Deflection caging is applied at the same time in a similar manner.

In addition to this mechanical action, the lever also actuates the ganged switches S101 and S106. Switch S101 interrupts the plate supply for all the amplifier channels (elevation, deflection, sensitivity, and range). When the amplifiers are inoperative, no signals are fed to the torque motors, which are already held steady by mechanical means. Thus although the gyro pickoffs continue to create signals, these signals are ineffective. Switch S106, ganged with S101, extinguishes the circle reticle bulb when the switch is placed in the cage position. At the same time, S106 energizes solenoid L201. The solenoid lifts the disk-shaped cover which shields the target index bulb. This bulb is the light source for the dot at the center of the reticle image. The dot is formed by a small hole at the center of a reticle. The reticle is placed between the bulb and the solenoid-operated cover, which is opaque except for a hole at its center. The reticle, however, is provided with an annular ring opening which permits passage of a circle of light as well as the central dot. When the cover is removed, the circle of light and dot are both projected on to the pilot's windshield. The image is fixed in position because the mirror mechanism is caged. The circle is also fixed in size, and should not be confused with the circle formed by the range prediction system. The two circles never appear simultaneously.

18. DEFLECTION PREDICTION

Deflection prediction is computed in essentially the same manner as elevation prediction. The principal data inputs are derived from the deflection gyro. This is mounted with its spin axis in the horizontal plane, parallel with the elevation axis of the airplane (Figure 4-26). The gimbal is inclined with its forward end down. Therefore the deflection component of the controlled line angular velocity is slightly reduced and a small roll component is added. The reason for this arrangement is based upon the fact that an airplane rolls as it turns (or tracks in deflection). The roll component furnished by the tilt of the gimbal improves the performance of the sight when tracking a target that is below the attacking airplane. The deflection gyro is not provided with an input from the gravity drop accelerometer, but otherwise the deflection data channel from gyro to torque motor is similar to the elevation channel shown in Figure 4-27. The mirror drive linkage between torque motor and mirror is different because it is necessary to tilt the mirror in a different plane.

The deflection torque motor is mounted in the deflection motor and mirror assembly. The armature shaft of the torque motor extends through one end of the housing. It carries the mirror drive ball-arm mounted transversely on its outer end. The ball on the ball arm engages a fork plate mounted on an arm that is rigidly connected to the mirror. When the arm is rotated by the torque motor, the mirror tilts in deflection. It should be remembered that the housing containing the linkage just described also supports the mirror. The housing, mirror, and deflection mirror drive are all rotated by the elevation mirror linkage.

19. RANGE PREDICTION

The range-prediction system receives from an outside source the information which represents target range. Under normal operation, a range signal is furnished by Radar Set AN APG-5. The radar set is not a part of the sight. In the event of radar set failure, a range signal from the manual range control unit of the sight may be substituted for the radar signal. Either signal performs two functions after its reception by the radar-range gear box of the sight. The two uses of either range signal are, first, to control elevation and deflection prediction by means of the sensitivity amplifier, and, second, to drive the mechanism which determines the size of the reticle image circle on the pilot's windshield. The range signal aplied to the prediction channels will be described first.

20. RANGE SIGNAL (PREDICTION)

This is a DC signal which originates in the radar range potentiometer R76 (Figure 4-35).

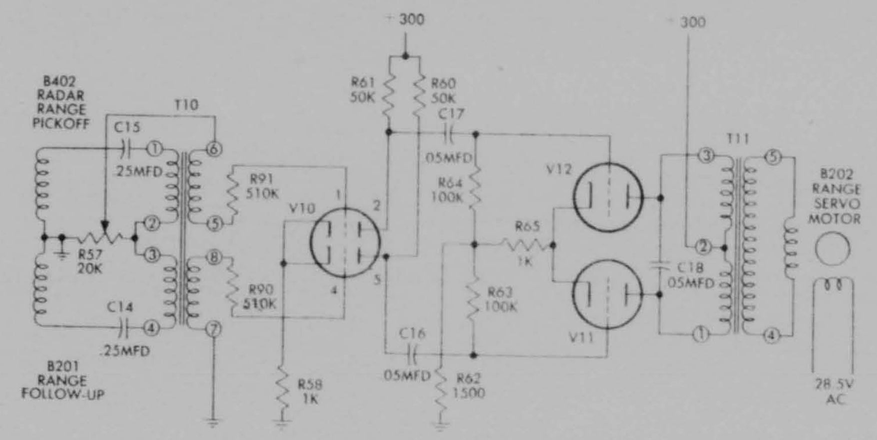

Figure 4-40. Range Amplifier, Simplified Schematic.

This potentiometer is located in the radar range gear box. It receives regulated DC from tube V5 in the sensitivity amplifier, and is grounded through R81 at its low end. The arm of the potentiometer is driven by the radar range motor B401. The motor, in turn, is driven by range signals (radar or manual) received from the radar junction box. The junction box is not part of the sight. The gear train connecting the drive motor B401 and the range potentiometer R76 includes a friction-disk, spring-loaded clutch, and two pairs of cams (Figure 4-37). The clutch protects the device in the event that the motor attempts to drive the potentiometer beyond its mechanical limits. The two pairs of cams convert the linear displacement of the motor rotor into non-linear displacement of the arm of R76. The motor displacement is proportional to target range. The potentiometer arm displacement is proportional to the reciprocal of range. This signal is combined with the air density signal and sent to the sensitivity amplifier. The output of the amplifier is used to modify elevation and deflection prediction as previously described.

21. RANGE SIGNAL (RETICLE SIZE)

This signal is an AC voltage which originates in the radar range pickoff B402. The pickoff rotor is driven by the same drive motor, and a portion of the same gear train, which drives the range potentiometer. The pickoff drive gearing omits one of the pairs of cams. The angular position of the rotor is proportional to the log of target range. The signal created in the pickoff as a result of the rotor position is applied to the range amplifier.

22. RANGE AMPLIFIER

The range amplifier (Figure 4-40) consists of tubes V10, V11, and V12, together with associated components. It is located in the amplifier unit. Its purpose is to create a signal which drives the range follow-up B201 in the sight head into correspondence with radar range pickoff B402 in the radar range gear box. After the follow-up has been driven to the correct position the output of the range amplifier becomes zero.

The signal supplied by the radar range pickoff is applied to primary winding 1-2 on input transformer T10 (Figure 4-39). The signal from range followup B201 is applied to primary winding 3-4 on the same transformer. Potentiometer R57 performs the same compensation function as the corresponding potentiometer in the elevation channel. The algebraic sum of the two signals is the input to

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the range channel. The amplitude of the resultant signal gauges the degree of misalignment between the pickoff and the follow-up. The phase of the signal is determined by the direction of the misalignment. Assume that at the instant under discussion this primary voltage induces secondary voltages that are positive at terminals 6 and 8. The voltage across winding 5-6 is impressed upon grid 1 of V10 through resistor R91, which limits excessive grid current when the grid is driven positive. The voltage across winding 7-8 is impressed upon grid 4 through R90. Tube V10 normally is conducting. For the signal polarity assumed, the voltage at plate 2 increases and the voltage at plate 5 decreases. These voltages are coupled to the grids of the power amplifiers V11 and V12.

The output tubes receive their plate supply through the center-tapped primary of output transformer T11. When the plate current of V12 increases and the plate current of V11 decreases, the change induces a voltage in the secondary of T11. The polarity of the secondary voltage, for the original condition assumed, would be positive at terminal 4. The secondary voltage is applied across one of the two stator windings of the range servo motor B202. The other winding of B202. The other winding of B202 is excited by 28-volt DC. The motor rotates when it receives a signal voltage from transformer T11. As the motor rotates, it also rotates the range follow-up B201, to which it is geared. Rotation continues until the follow-up is in electrical correspondence with pickoff B402. When this occurs, the signal input to the range amplifier is reduced to zero and the range motor B202 stops. The direction of motor rotation depends upon the phase relation between voltage in the winding excited by the amplifier and the voltage in the winding excited by 28-volt AC. The phase of the amplifier winding is determined by the phase of the input to the amplifier at transformer T10, as outlined in the preceding paragraphs.

23. RANGE CONE DRIVE

The range servo motor B202, and range follow-up B201 which is geared to B202, control the reticle size by means of the range cone drive (Figure 4-32). The gear train which connects B202 and B201 drives a cam. The associated cam follower translates a guide rod. The motion of the guide rod is transmitted by means of the range cone link to the illuminator tube. This tube is solid, made of quartz, and placed so that light from the circle bulb shines into one end. At the other end is an opaque cap and the side of the tube, except for a narrow band near the cap end, is coated with an opaque finish. The light shining through the tube emerges through the band, or ring.

The capped end of the tube projects into the vertex of the 90-degree range cone, the cone and tube axes being coincident. The inside surface of the cone reflects light which strikes it from the clear, ring-shaped area on the tube. The reflected light pattern is a circle, and is the source of the reticle image circle which appears on the pilot's windshield. The size of the circle increases as the illuminator tube moves deeper into the range cone, and decreases as the illuminator tube recedes. Thus the size of the reticle circle is controlled by the range data received from the Radar Set AN/APG-5.

24. MANUAL RANGING

In the event of radar set failure, the pilot may insert range data manually. Before this is done, however, he must position the span cam (Figure 4-32), which inserts target size data into the sight. The span cam is positioned by means of the wingspan knob at the left end of the sight head. This knob, by means of a gear-cam-link mechanism, translates the illuminator tube to a position determined by target size. After this adjustment has been made, further translation of the illuminator tube is accomplished by means of the manual range control unit.

The manual range control unit is connected by a flexible shaft to the handle of the pilot's throttle control. The pilot can rotate the shaft by rotating the throttle handle grip. Rotation of the shaft first operates two switches (S80 and S81) and then a potentiometer (R80), all located in the manual range control unit (Figure 4-41). The pilot rotates the handle grip so as to keep the target continuously and ac-

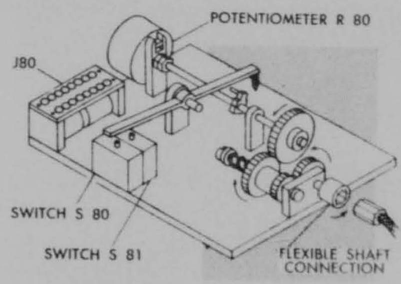

Figure 4—41. Mechanical Schematic, Manual Range Control.

curately framed by the reticle image circle. The switches set the radar junction box (not part of the sight) for manual range operation or for radar range operation. The potentiometer is furnished with dc from the sight. It picks off a voltage, as determined by its setting, which is sent to the radar junction box through S80. The junction box returns this signal to the radar-range gear box of the sight, where the signal operates motor B401. At this point the flow of range data becomes identical with the flow when radar range data is supplied.

25. OPTICAL SYSTEM

The optical system of the sight consists of the optical components which present the reticle image to the pilot. The components are closely related to the elevation, deflection and range prediction elements. As these portions of the optical system have been described previously, they will be discussed only briefly in the following paragraphs.

Two sources of light are used to produce the reticle image on the pilot's windshield. One, the reticle circle bulb, is the light source for the variable-diameter circle. The other, the target index bulb, is the source for the reticle index dot and also for the fixed-size circle. The fixed-size circle appears only when the sight is being used as a fixed sight. The reticle circle bulb (for the variable size circle) furnishes the light which shines through the illuminator tube. Emerging from the illuminator tube it is shaped into a circle (or annular ring) by the range cone and reflected to the pellicle. The pellicle is a flat, oval-shaped, transparent film. It is rigidly mounted so that the light from the range cone strikes it at 45 degrees. The light is reflected by it and does not pass through it appreciably. The pellicle reflects the light from the range cone upward to a mirror which is fixed in position. The mirror reflects the light, through a collimating lens, to the flat, oval-shaped mirror which is rotated in elevation and deflection. This is the boresight mirror, indicated in Figure 4-32. Its angular position determines the precise angle at which it reflects the beam of light forming the reticle circle. The light always is reflected upward to an optically flat area of the airplane's windshield. The angle at which the light meets the windshield causes the image to appear as a circle, not as an ellipse. The image also appears to the pilot to be at an infinite distance in front of him because the collimating lens projects the light which passes through it in parallel lines.

The second light source in the optical system, the target index bulb, is mounted directly below the pellicle at the lower end of a tube. The upper end of the tube, under normal conditions, is closed by a cover. The cover is pierced at its center by a small hole which permits a narrow shaft of light to project vertically upward to the pellicle. The light strikes the pellicle at an angle of 45 degrees and at the center of the light ring formed by the range cone. The light passes through the pellicle, and follows the same path as the light which forms the reticle circle. At the windshield, the light provides the dot at the center of the circle.

When the sight is used as a fixed sight, the cover carrying the index dot hole is swung upward. This action permits light from the target index bulb, which has passed through a reticle, to reach the pellicle. The reticle is an opaque disk pierced not only by a hole similar to the hole in the cover but also by three arcs which form an almost complete circle. Light from the target index bulb passes through the hole and circle in the reticle upward to the pellicle. At the time when the cover is swung upward from its normal position, the light reaching the pellicle from the range cone is extinguished automatically. The pellicle therefore receives light from the target index bulb only. This light, passing through the

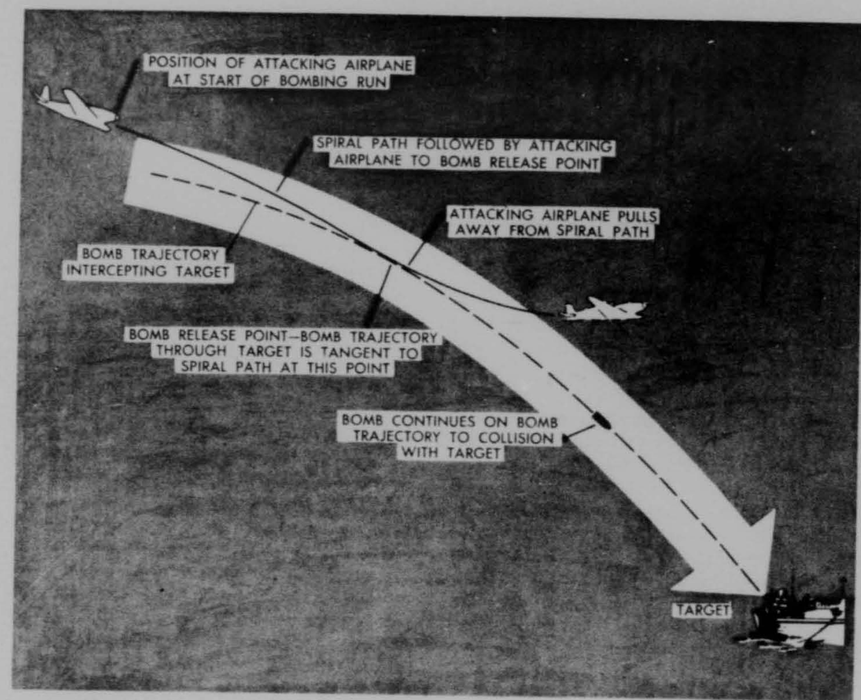

Figure 4–42. Spiral Path Bomb Trajectory.

pellicle, follows the path previously described. At the windshield the light forms an image consisting of a fixed-size circle with a dot at its center.

26. ELEVATION PREDICTION

General. When the sight is used for bombing, the pilot flies his airplane along a path which will keep the reticle image dot, or index, continuously aligned with the target. He keeps his wings horizontal so far as permitted by the necessity of making tracking corrections. The only requirement in choosing the position from which to start a bombing run is that the resulting course at some point will be tangent to a bomb trajectory intersecting the target. No range, altitude, or dive angle inputs are required, although range data is not cut off. When the proper release point is reached, the reticle circle image disappears (the circle bulb is extinguished). In normal operation, the bombs are dropped automatically, although manual control may be substituted.

During a bombing run, the reticle image dot is depressed below the controlled line (Figure 4-24) by a constant angle in elevation. In deflection, the sight mechanism continuously introduces a prediction angle to correct for the relative motion between the target and the attacking airplane. The relative motion is caused by components of the wind and target velocity across the line of sight. The depression of the reticle image dot forces the pilot to fly a spiral type of course toward the target in a vertical plane (Figure 4-42). In following the spiral path, the velocity vector of the airplane continuously changes direction. When the velocity vector becomes tangent to a bomb trajectory through the target, a definite relationship is reached between the angular velocity and the linear acceleration of the airplane. This relationship is detected by the superelevation assembly (bombing accelerometer) and the elevation gyro. Their data outputs combine to extinguish the reticle circle bulb and to actuate the bomb release relay. The effect of the airplane speed is introduced by an aneroid bellows in the superelevation assembly, which makes it possible for the sight to operate over the entire speed range of the airplane.

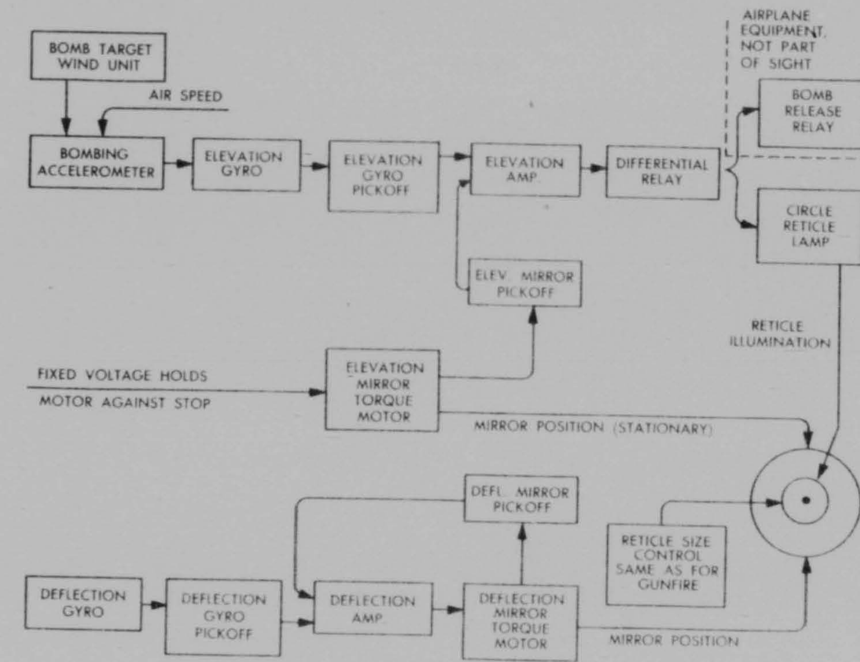

Figure 4–43. Bombing, Simplified Block Diagram.

The actual functioning of the sight when used for bombing (Figure 4-43) is similar in many respects to operation for gunfire (Figure 4-27.) Deflection and elevation prediction for bombing differs from prediction for gunfire in that the bombing function does not utilize any stiffness motor control (as is indicated in Figure 4-44). With this exception, however, the deflection channel operates in the same manner in each function. The principal difference beween the bombing and gunfire functions occurs in the elevation channel. During a bombing run the elevation amplifier does not control the position of the mirror, which is held stationary. The amplifier output is applied instead to a differential relay. This relay, when actuated, operates the bomb release relay in the airplane and also extinguishes the circle reticle bulb in the sight. The following paragraphs discuss the means used to accomplish these results.

27. BOMBING ACCELEROMETER (SUPERELEVATION ASSEMBLY)

The superelevation assembly is used only when the sight is in the bombing function. When the sight is to be used for this purpose

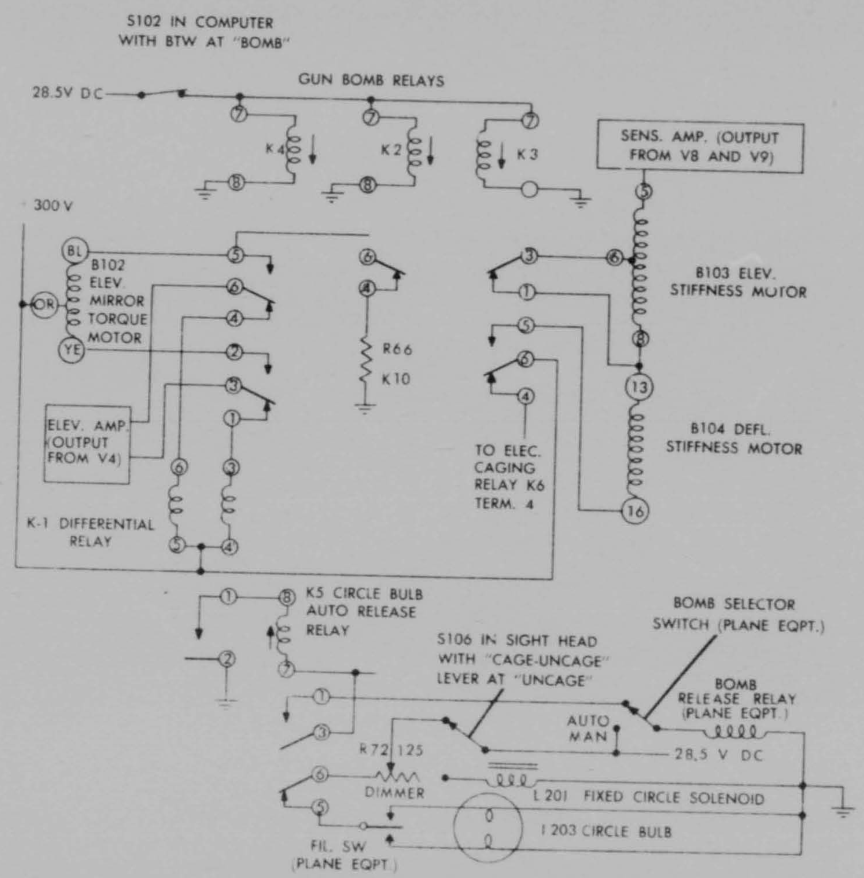

Figure 4-44. Gun-Bomb Relay Switching Circuits, Simplified Schematic.

the knob on the bomb target wind unit is turned to the "bomb" position and adjusted to the setting indicated by the pilot's estimate of wind at the target. The knob is connected by means of a universal joint shaft to a cam on the bombing accelerometer in the computer. Rotation of the cam engages a ball arm on the accelerometer with a fork arm on the gimbal of the elevation gyro. The effect of this connection is to apply a weight and lever arm to the gimbal. The cam also is used to adjust the effective length of the lever arm to correspond with the wind estimate. The weight and lever prevent precession of the gyro, holding the gimbal against a stop. The weight responds, by its tendency to move, to the acceleration and the diving angle of the airplane. Its tendency to move also is controlled by air speed by means of an aneroid bellows which is supplied with air pressure through pitot and static tubes. Furthermore, a counterweight on the bombing accelerometer lever arm cancels the effect of the gravity drop ac-

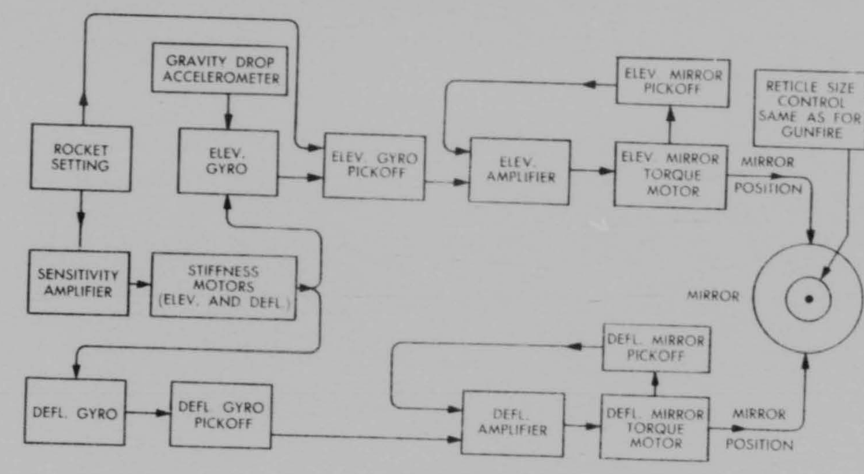

Figure 4-45. Rocketfire, Simplified Block Diagram.

celerometer. When the airplane reaches the point in its spiral approach when the precession tendency of the gyro overcomes the restraint of the accelerometer weight, the gyro gimbal moves.

28. ELEVATION GYRO PICKOFF

The gyro pickoff armature shaft is connected mechanically to the gyro gimbal, as stated in the discussion of the gunfire function. When the gyro gimbal is held against the stop, the signal output of the pickoff is constant. When the gyro gimbal starts to move, the pickoff signal changes from this constant value. The signal at all times is sent from the pickoff B103 to the elevation amplifier input transformer T5. Connections are the same as for the gunfire function and are shown in Figure 4-31.

29. ELEVATOR TORQUE MOTOR AND MIRROR PICKOFF

The elevation mirror torque motor, when the sight is in the bombing function, does not receive the same input that it receives during gunfire. The torque motor receives instead a DC voltage of constant value. This voltage holds the torque motor at a fixed position. The torque motor armature shaft holds the mirror steady at a position which depresses the reticle image by a fixed $9\frac{1}{2}$ degrees. As the position of the armature shaft is fixed, the mirror pickoff signal is also unchanging because the pickoff armature is mounted on the same shaft. This signal remains unchanged during the time that the sight is in the bombing function. The signal is not affected when the gyro starts to precess. Furthermore, this signal has the same magnitude as the signal output of the gyro pickoff when the gyro is held against its stop by the bombing accelerometer. The signal is sent from the elevation mirror pickoff B102 to the elevation amplifier input transformer T5. Connections are the same as during gunfire and are shown in Figure 4-31.

30. DIFFERENTIAL RELAY

The differential relay K1, when the sight is in the bombing function, is placed in the plate circuit of the elevation amplifier output tube V4. It replaces the elevation-mirror torque motor B-102, as indicated in Figure 4-44. When the inputs to the elevation amplifier are equal, that is, when the bombing accelerometer holds the gyro against the stop, the current in one coil of differential relay K1 is the same as the current in the other coil. Under

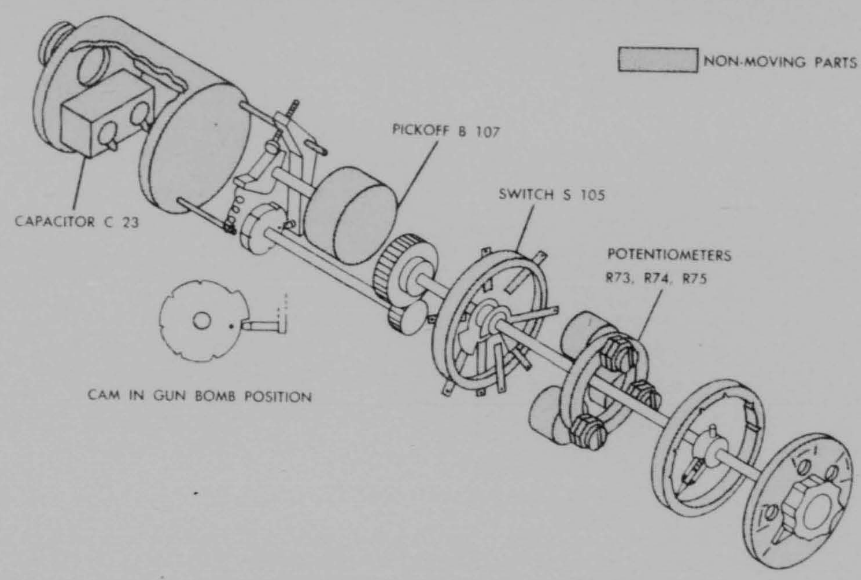

Figure 4-46. Mechanical Schematic, Rocket Setting Unit.

this condition the relay is not energized and contacts 1 and 2 are open. When the inputs to the elevation amplifier are unequal, that is, when the gyro starts to precess, more current flows through one relay coil than through the other. Contacts 1 and 2 then close; relay K5 becomes energized, closing contacts 1-3 and opening contacts 5-6 (Figure 4-44). Contacts 1 and 3 furnish 28 volts DC to the bomb-release relay, provided that the bomb-selector switch is at the "automatic" position. Contacts 5 and 6 break the circuit to the circle reticle bulb 1203, and the circle reticle image is extinguished.

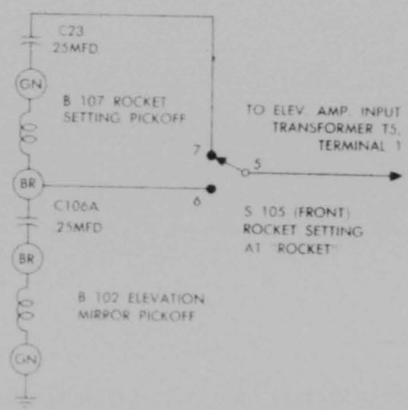

Figure 4-47. Elevation Amplifier Input Circuit for Rocketfire, Simplified Schematic.

31. ROCKETFIRE SOLUTION

The operation of the sight when used for rocketfire is similar in many respects to gunfire operation. The similarity may be noted in Figure 4-45. The size of the reticle circle is controlled in the same manner, by range data. Deflection prediction is accomplished as in gunfire. A fixed sensitivity control, however, is applied to the deflection stiffness motor and the elevation stiffness motor instead of the range and air density control used in the gunfire function. Elevation prediction differs in that a fixed depression of the reticle image in

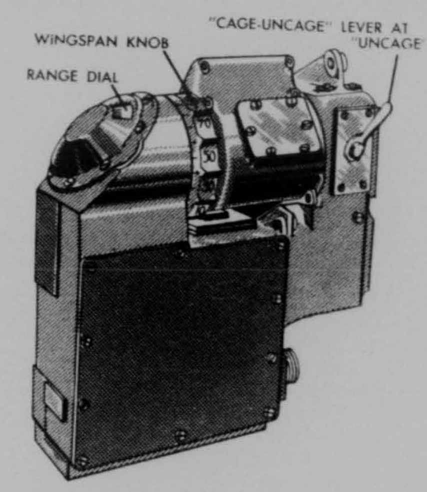

Figure 4-48. Sight Head.

elevation is applied as in the bombing function. Instead of a constant depression at all times, however, the depression is adjusted for the particular type of rocket to be used.

32. ROCKET SETTING UNIT

The rocket-setting unit includes the pickoff B107 (Figure 4-46). The rotor of B107 is turned by the rocket-setting knob, which also operates the wafer-type switch S105 within the unit. The rear contacts of the switch are connected in the sensitivity amplifier input circuit as shown in Figure 4-35. When the rocket setting knob is at "gun-bomb" the density potentiometer and the radar range potentiometer control the input to the sensitivity amplifier. When the knob is set at any of the three "rocket" positions these two potentiometers are removed from the circuit. In their place is substituted one of the three identical variable resistors R73, R74, or R75. These resistors provide that a constant voltage is fed to the sensitivity amplifier as the data input.

The front contacts of S105 are connected in the elevation amplifier input circuit as shown in Figure 4-47. When the rocket setting knob is turned from the "gun-bomb" position to any of the three "rocket" positions, contacts 5 and 7 on S105 close. This action places rocket setting pickoff B107 in the input circuit of the elevation amplifier. The pickoff is connected in series with elevation mirror pickoff B102. The rocket setting knob, in addition to operating S105, turns the rotor of rocket setting pickoff B107. This action causes the pickoff to generate a signal which depresses the reticle image in elevation. The rocket setting pickoff continues to supply this depression signal as long as contacts 5 and 7 on S105 remain closed. The magnitude of the depression is determined by the particular "rocket" position at which the rocket setting knob is placed.

33. OPERATING INSTRUCTIONS

Whenever the airplane power source is in operation, 115-volt, 400 cycle, single-phase current is supplied to the phase inverter, which is also airplane equipment and is not part of the sight. The phase inverter supplies 28.5-volt, 400 cycle, three phase current to the stators of the gyros in the sight. Thus the gyros are spinning whenever the airplane's power source is in operation. Furthermore, the airplane's power source supplies 28.5-volt DC to the heaters which control the temperature of the fluid in the dampers on the stiff-

Figure 4-49. Rocket Setting Pointer.

Figure 4—50. Bomb Target Wind Pointer.

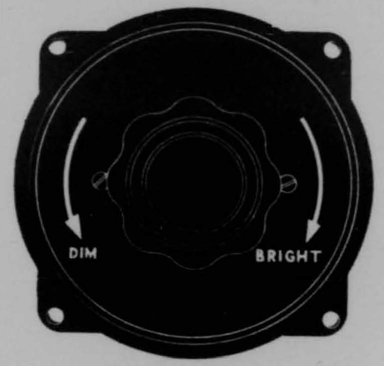

Figure 4—51. Dim-bright Knob.

ness motor armature shafts, and also to the space heaters in the computer. Therefore the following instructions assume that the gyros are spinning, that the dampers are at the correct temperature of approximately 160 degrees F (70 degrees C), and that the space heaters are maintaining the correct air temperature of approximately 135 degrees F (57 degrees C) in the computer, before the sight is started. If the heaters have not been energized, it will be necessary to operate the airplane's power source and energize the heaters for twenty minutes before starting the sight.

34. STARTING

To start the sight, the "sight master" switch (airplane equipment) is placed at "on" (provided that power already has been supplied as described in the previous paragraph). After a short wait (one minute) to permit the amplifier tubes to heat up, the sight is ready for operation.

A check should be made to see that the reticle image, a circle with a dot at its center, appears on the windshield (Figure 4-44). The reticle image is checked further by moving the "cage-uncage" lever from one position to the other (Figure 4-48). The dot should flicker as the lever is moved and the circle should change to three circular arcs.

35. GUNFIRE OPERATION WITH RADAR RANGE

The following controls must be in the positions indicated.

Rocket-setting pointer (Figure 4-49) at "gun-bomb."

Bomb-target wind pointer (Figure 4-50) at "rocket-gun."

Manual-range control on throttle in descent (at clockwise end of rotation).

"Cage-uncage" lever on sight head (Figure 4-48) at "uncage."

"Dim-bright" knob (Figure 4-51) at the position which gives satisfactory reticle illumination.

When searching for targets, the push-button type of caging switch is pressed on the left grip of the control stick. This action will stabilize the reticle image and prevent spurious prediction when tracking begins. "Tracking" may be defined as the act of minimizing the difference between the target position and the apparent position of the reticle image by controlling the attitude of the attacking airplane.

When a target is located and tracking is started, the push-button type of caging switch is released. The reticle image will swing from the target. The airplane should be flown so that the reticle image is continuously and

accurately centered on the target. The reticle circle will change in size as the range changes. The circle will become larger as the range decreases and smaller as the range increases. This action is controlled automatically by the radar set associated with the sight. After the target has been tracked smoothly, without slipping or skidding, for four or five seconds, fire the guns.

36. GUNFIRE OPERATION WITH MANUAL RANGE

The position of each control for this function is the same as the position for gunfire operation with radar range, with one addition and one exception. The additional control is in the wingspan knob (Figure 4-48). This knob is graduated with markings from 30 feet to 120 feet. It must be set to correspond with the wingspan of the target being attacked. The exception previously mentioned is the manual range control on the throttle. The setting of this control is described in the following paragraph.

Searching for a target is carried out in the same manner as for gunfire operation with radar range. Tracking, however, requires operation of the manual tracking control as the target is being tracked. This control governs the size of the reticle image circle. When the control is turned clockwise the diameter of the circle decreases. When the control is turned counterclockwise the diameter of the circle increases. The control should be turned so that the circle continuously and accurately "frames" or encloses, the target. As range decreases, the size of the circle must be increased. As range increases, the size of the circle must be decreased. When the attitude of the target foreshortens or obscures the wingspan dimension, the size of the circle must be determined by good judgment. After the target has been framed and tracked smoothly for four or five seconds, without slipping or skidding, fire the guns.

37. BOMBING OPERATION

A check should be made to see that the following controls are in the positions indicated.

Rocket-setting pointer (Figure 4-49) at "gun-bomb."

Bomb-target wind pointer (Figure 4-50) at "bomb" sector of the dial and at the figure corresponding to the estimated wind speed at the target.

"Cage-uncage" lever on sight head (Figure 4-48) at "uncage."

"Dim-bright" knob (Figure 4-51) at the position which gives satisfactory reticle illumination.

"Bomb-selector" switch (airplane equipment) at "auto" if it is intended to release the bombs automatically. It should be set at "manual" if it is intended to release the bombs by means of the "bomb-release" button (airplane equipment).

Searching for targets is carried out in the same manner as during gunfire operation with radar range. Tracking, or the bombing run, is not the same. The reticle image position is depressed at a fixed angle as a result of the adjustment made on the bomb-target wind unit. This depression makes it necessary to fly the airplane along a downward curve in a vertical plane, or bombing spiral, in order to keep the reticle image aligned on the target.

The bomb-release point is the point on the bombing spiral where the path of the airplane is tangent to a bomb trajectory. At this point the reticle image circle is extinguished automatically, and a red, flashing light is reflected on the windshield. If the "bomb-selector" switch was set at "auto," the bombs will be released automatically. If the "bomb-selector" switch was set at "manual," the "bomb release" button is pressed to release the bombs.

38. ROCKETFIRE OPERATION

A check is made to see that the following controls are in the positions indicated.

Rocket-setting pointer (Figure 4-49) at the "rocket" sector of the dial corresponding to the rocket being used. The pointer is set to "S" on the sector if a steep dive angle is to be used. The pointer is set to "N" if a normal dive angle is to be used.

Bomb-target wind pointer (Figure 4-50) at "rocket-gun."

Manual-range control on the throttle in descent (at clockwise end of rotation).

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"Cage-uncage" lever on sight head (Figure 4-48) at "uncage."

"Dim-bright" knob (Figure 4-51) at the position which gives satisfactory reticle illumination.

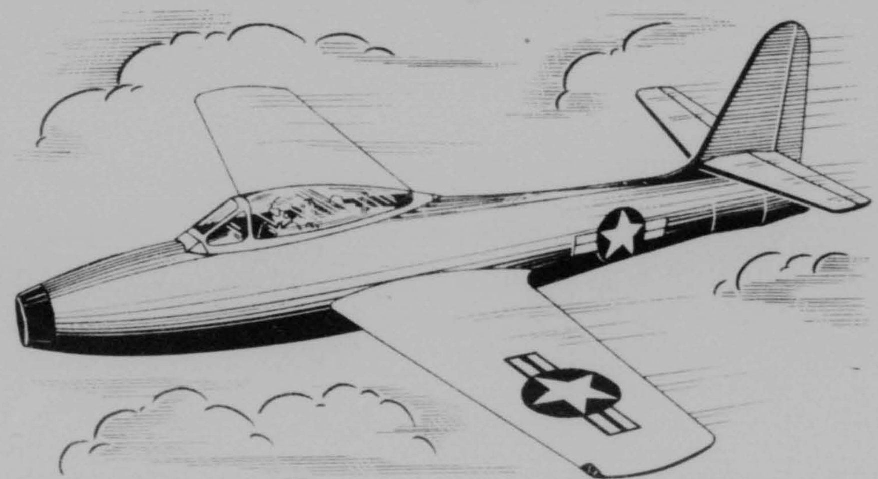
Searching for targets is accomplished in the same manner as for gunfire operation with radar range. Tracking targets is accomplished in the same manner as for gunfire operation with radar range or manual range, as the case may be.

39. FIXED SIGHT OPERATION

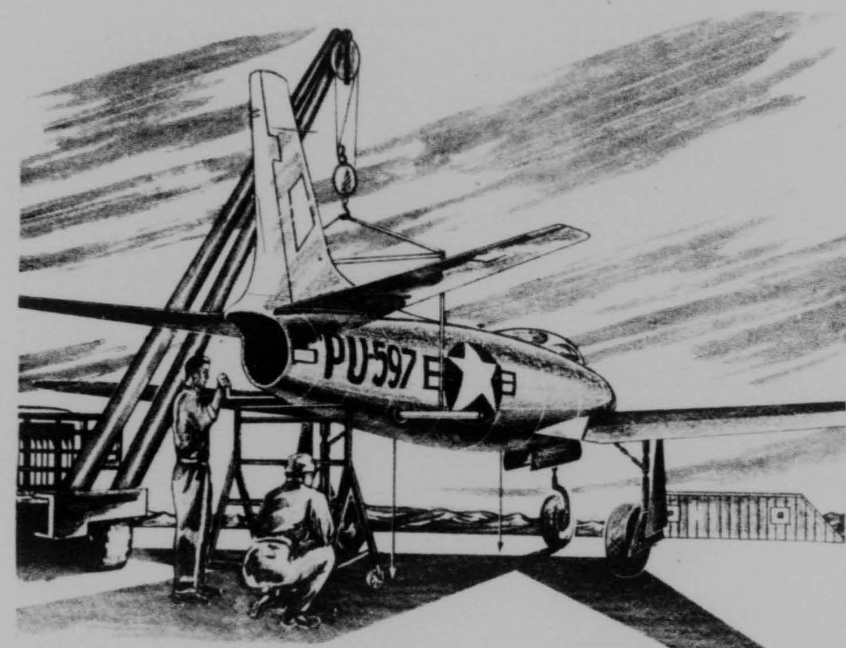
The sight may be used as a fixed "ring sight" if desired. It is superior to the usual ring sight because the reticle image appears to be at an infinite distance from the pilot. A two-inch sideways motion of the pilot's head, for example, will not cause misalignment of the reticle image and target. Instead, it will cause an apparent two-inch motion of the reticle image on the target, which is negligible. The sight may be used as a fixed sight after placing the "cage-uncage" lever on the sight head (Figure 4-48) at "cage." When the sight is used in this manner no prediction angle is generated and the diameter of the reticle circle remains constant.

40. STOPPING

To remove the sight from operation place the "sight master" switch (airplane equipment) at "off." Also place the "cage-uncage" lever on the sight head at "cage" (Figure 4-48). The gyros will continue to spin, the heaters for the dampers on the stiffness motor armature shafts will remain energized, and the computer space heaters will remain energized. These items continue to function as long as the airplane's power source supplies power.



CHAPTER 5—HARMONIZATION



1. GENERAL

Harmonization is the process of adjusting the gun sight, boresighting the guns and camera so that the sight line will be parallel to the flight line and so that the camera will record the action during the firing period. At different airspeeds, gross weights and altitudes variance exists between the fuselage reference line and the flight line. In the F-84, the airplane tends to fly nose up. At 20,000 ft. altitude with a gross weight of 12,000 lbs. the airplane will have a seven mil nose-up altitude when the airspeed is 549 miles per hours. The guns are adjusted so that their fire parallels the sight line at the desired range under these conditions. By leveling the airplane to the sight-adjustment mark which is seven inches above the gun-sight marks on the target, and then boresighting the guns, gun sight, and camera to their respective crosses, the desired 7 mil nose-up condition is obtained without changing the airplane's level position. If it is desired to boresight for a different airspeed, position of sight-adjustment mark is changed accordingly. The gunsighting chart, Figure 5-1 contains the data for various other conditions of speed.

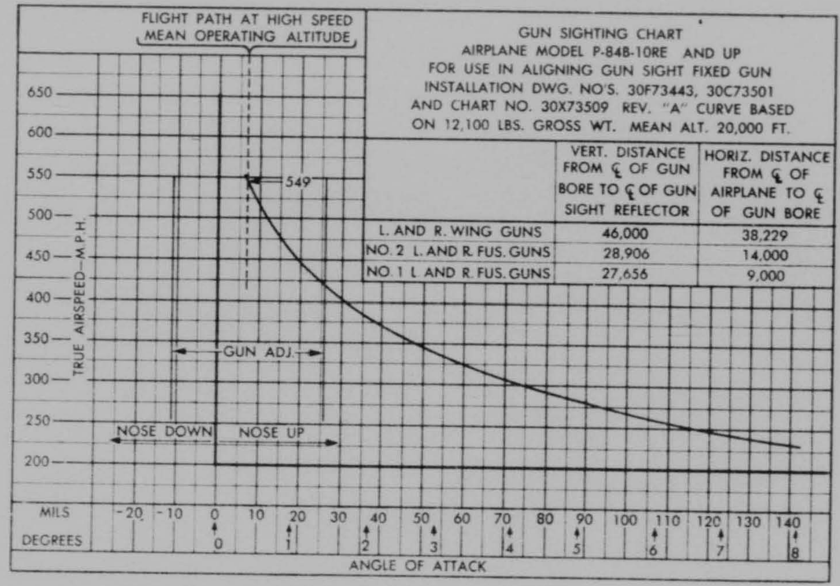


Figure 5—1. Gunsighting Chart.

2. TARGET PREPARATION

Manufacture a target in accordance with Figure 5-2. The target must be adjustable so that it can be raised or lowered or moved laterally.

Preparing the Airplane

A suitable location is selected that will provide at least 100 feet of level surface.

The airplane is jacked up. See Figure 5-3.

Note: Screw-type jacks will be used if available, as hydraulic jacks have a tendency to creep.

A spirit level is placed across the leveling lugs in the cockpit and the airplane is levelled laterally by adjusting one of the wing jacks. The longitudinal-level lugs are stowed on the left longeron in the gun deck. When in use they are bolted to the plate nuts in the top of the longeron. The transverse-level lugs are on the cockpit longerons. By placing spirit levels on the lugs the amount of jack adjustment necessary to level the airplane can be determined.

The gun deck cover is removed and the longitudinal leveling-lugs are installed on the top side of the longeron. The longitudinal level-lugs are stowed on the left longeron in the gun deck. When in use they are bolted to the plate nuts in the top of the longeron. The transverse-level lugs are on the cockpit longerons. By placing spirit levels on the lugs the amount of jack adjustment necessary to level the airplane can be determined. Normally, the lugs are stowed on the side of the longeron. A spirit level is placed on the lugs and the airplane is levelled longitudinally by adjusting the nose jacks.

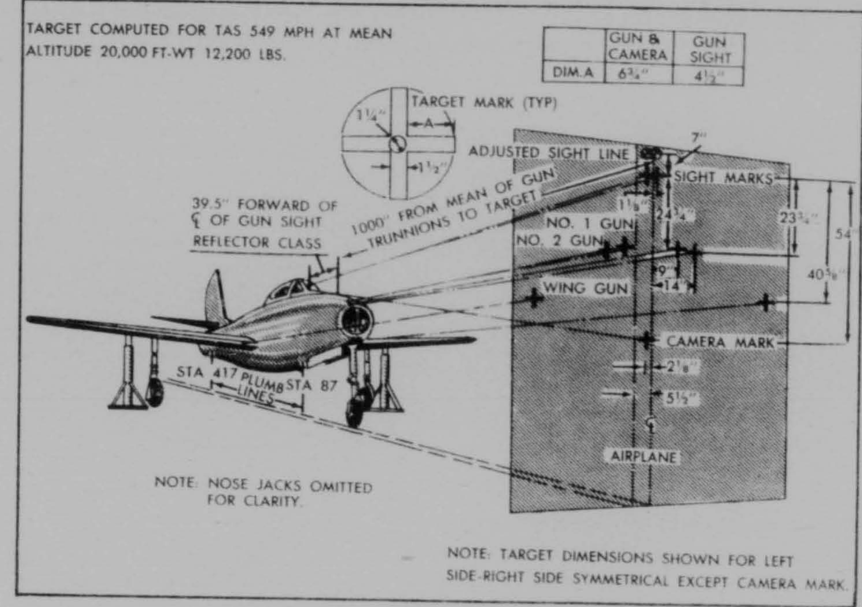


Figure 5—2. Boresighting Target.

Plumb bobs are suspended from the plate nuts on the lower right-hand side of the fuselage marked "Gun Sight Alignment." These plate nuts are five and one half inches from the vertical center line of the airplane, at stations 87 and 417.

The plumb bobs are adjusted so that they are approximately one inch from the ground.

Note: If the suspended plumb bobs sway too freely due to the wind, they should be immersed in receptacles containing oil to reduce sway.

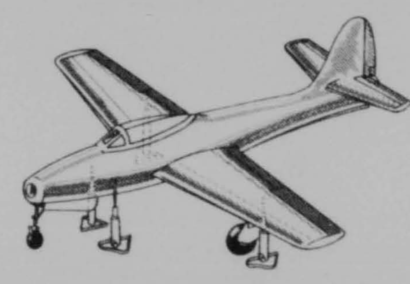


Figure 5—3. Normal Jacking Arrangement.

The target surface is placed at right angles to the longitudinal axis and in front of the airplane, at a distance of 1,000 inches, measured from the center line of the mean pivot point of the gun trunnions.

Note: The mean pivot point of the gun trunnions is 39.5 inches forward of the center of the gunsight reflector glass.

The target is levelled laterally and raised or lowered so that its mid-point approximates that of the airplane's nose.

From a position aft the airplane, one sights along the plumb lines. The eye is kept at a sufficient distance behind the aft bob line, so that both bobs are clearly visible, and the target is moved laterally to align the plumb lines with the vertical line on the target which is five and one half inches to the right of the target's vertical center line.

A sight-line level indicator is placed (Type A-2) on the gun sight glass reflector.

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Note: It is important that the windshield glass is clean.

The level is rotated by means of the knob of the frame until the hand level is approximately horizontal with the level bubble thereof on top.

By looking through the small hole in the eyepiece of the hand level, the knob is adjusted until the bubble, which is visible through the eyepiece, is centered on its reference mark.

Next, one sights through the indicator and the target is raised or lowered to align the sight adjustment mark on the target with the bubble reference mark in the level.

The level indicator is removed.

The target is now ready for boresighting and should be affixed in position.

3. SIGHT ADJUSTMENT (K-14B)

External power is connected to the airplane.

Armament selector switch is turned to "Sight and Camera." Gunsight selector control is turned to "Fixed and Gyro." Dimmer control is turned to "BR'T." If sight has adjustable reflector glass dial is turned to zero. Starting with airplane Serial No. 46-638 the gunsight controls have been changed by the addition of a relay and resistor to the selector dimmer, by the installation of a "Rocket Sight" switch on the throttle twist grip. These changes will permit the installation of a modified sighting head which will include an adjustable reflector glass. The reflector glass can be tilted by operating a calibrated knob on the side of the sight. By changing the angle of the reflector glass the sight line can be deflected for rocket firing. A chart installed in the nose-wheel well lists the various dial settings in degrees and the corresponding angular deflection of the sight line. When it is desired to use the gunsight as a rocket sight the pilot presses the switch on the throttle. This actuates a circuit through the relay and resistor which, in effect, cages the gunsight gyro.

Sight is allowed to warm up for ten minutes. Range control is set to 1,500 feet.

Gunsight position is adjusted so that gyro sight aligns with the right hand cross on the target. Elevation adjustments are made at the vertical screw in the sight mounting bracket. Locknut is tightened after completing elevation adjustment. Adjustment for azimuth is made by turning the two screws by which the mount is pivoted in its bracket. If additional azimuth adjustment is necessary the mounting bolt is loosened and the sight head rotated. The adjustment is accomplished by the differential-toothed adjusting ring. This ring, containing 109 fine teeth on one side and 36 coarse teeth on the other, is sandwiched between the fine-toothed ring attached to the base of the sighting head, and the coarse-toothed ring incorporated in the mounting bracket. This arrangement permits large and small adjustments to within plus, or minus one mil. A movement of the sighting head combined with the differential ring as a unit, of one large tooth, represents 10 degrees, while a movement of the sighting head alone, of one small tooth, represents 3.30 degrees. To make this latter adjustment the mounting bolt must be removed and the retaining ring loosened.

The silica gel cell is removed from the sight and by trial and error adjustment of the two screws projecting from the plate assembly near the gyro motor on the back of the sight, the center of the cross in the fixed sight is brought to align with the left hand cross on the target.

The sight is turned off and external power is disconnected from airplane.

4. SIGHT ADJUSTMENT (A-1B)

The two cover plates on the sight head that expose the sight boresight and adjustments are removed.

The electrical caging button (on the stadiometric control) is depressed and held in the depressed position.

Rocket Setting Unit is placed on Gun, and Bomb Target Wind Unit on Gun.

Sight master switch is turned On. The reticle image should appear on the sighting glass.

Uncage-Cage lever is placed at Uncage.

Elevation-adjustment lock-nut is loosened.

While observing the relation between the reticle-image dot and the reference point on the boresight target, the elevation adjustment nut is turned until the reticle image and reference point are aligned in elevation. The reticle image and reference point must be aligned when the wrench is not touching the adjusting nut or any of the moving mechanism.

The lock-nut is tightened carefully to avoid changing the position of the adjusting nut. The alignment is rechecked.

The deflection boresight adjustment screw is loosened.

While observing the relation between the reticle image and the reference point on the boresight target, the deflection adjusting cam is turned until the reticle dot is aligned with the reference point in deflection. The reticle image and reference point must appear to be aligned when the screwdriver is not touching the adjustment or any of the moving parts.

The locking screw is tightened carefully without changing the position of the adjusting cam. The alignment is rechecked.

Both elevation and deflection alignments are rechecked and if not correct, the above procedure is repeated.

Caging button is released. Cage-Uncage lever is placed at Cage, sight master switch is turned Off, and cover plates are replaced on sight head.

5. BORESIGHTING THE GUNS

Note: It will facilitate boresighting if the outboard nose guns are boresighted before the inboard nose guns are installed. The following procedure is applicable when boresighting any gun.

Gun deck and or wing gun-bay covers are removed.

Electrical plug is disconnected from gun solenoid.

The cover plate is lifted off the gun receiver.

The ammunition belt is disconnected from the gun receiver.

For the nose guns, the anti-siphoning pin is inserted to lock the ammunition belt.

Gun is charged to remove unfired round.

Muzzle or breech tool from J-1 or J-2 boresighting kit is inserted. The muzzle tool cannot be used for boresighting the fuselage guns due to the position of the guns in the blast tubes.

To insert breech tool, the gun cover is opened, the bolt moved back and locked. Care must be exercised when inserting the breech tool, as accidental release of the bolt will injure the armorer, and destroy the tool. If convenient, the backplate may be removed, the driving spring released and the bolt moved rearward. In the latter condition, there is no danger of the bolt being forced forward.

The gun is aligned to its respective cross on the target. All adjustments are made at the lockbolt assembly.

Elevation adjustments are made by means of the two vertical screws in the lockbolt. The lockwire is cut and the retainers are rotated out of the way. Both screws are turned simultaneously to raise or lower the gun.

Azimuth adjustments are made by adjusting the Allen head screws on each side of the cam locks. Each locknut is loosened with the special wrench (30X19711) and the screws are turned in or out to obtain the necessary alignment (See Figure 5-4).

After adjustment, the locknuts are tightened to hold the azimuth setting and the retainers are lockwired in their down position to lock the elevation adjusting screws.

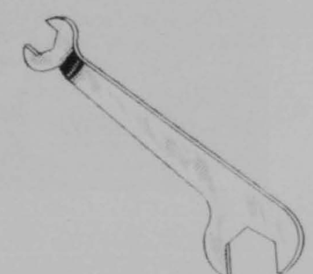


Figure 5–4. Wrench—.50 cal.

The boresighting tool is removed.

The backplate is replaced if it was removed.

The feed chute is connected.

The gun receiver cover is closed.

The plug is reconnected to the gun solenoid.

The longitudinal-leveling lugs are removed and stowed on the gun deck longeron (See Figure 5-5).

The access covers are replaced.

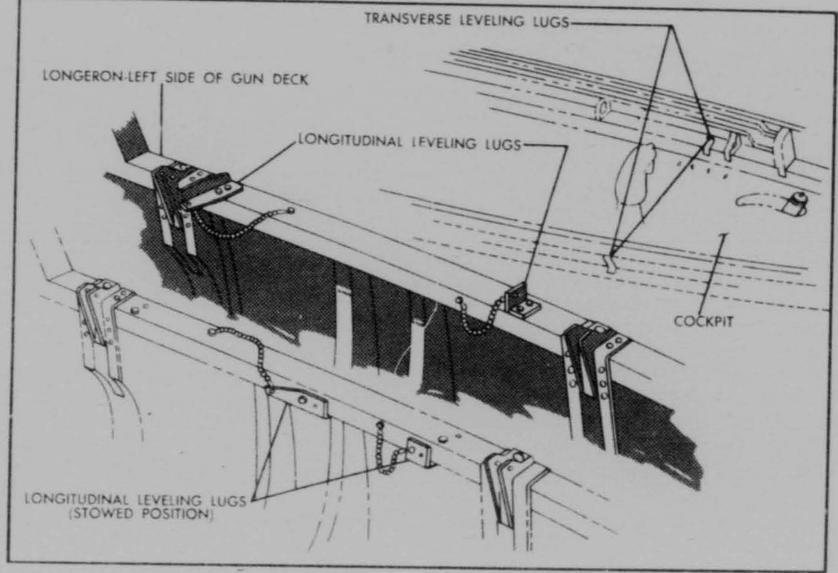
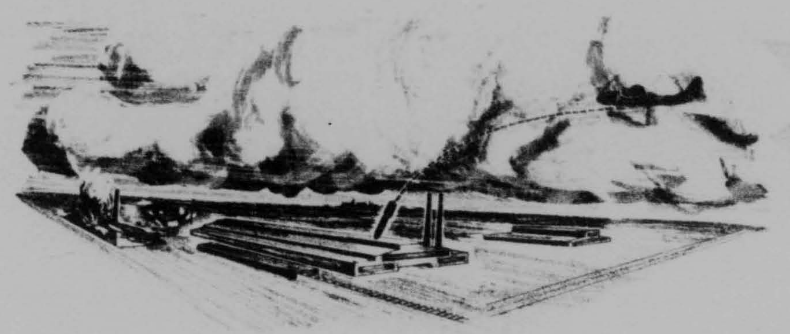


Figure 5—5. Longitudinal Leveling Lugs and Gun Deck Longeron.

CHAPTER 6—RADAR BOMBING EQUIPMENT



SECTION I—INTRODUCTION TO RADAR

1. MEANING OF RADAR

Radar means "radio direction and ranging." The basic principles upon which its functioning depends are simple. Therefore, the seemingly-complicated series of electrical events encountered in radar can be resolved into a logical series of functions.

2. PRINCIPLE OF OPERATION

The principle upon which radar operates is simple. Briefly, it consists of creating and detecting a radio echo. Some of the sound waves sent out by a loud shout may strike against a wall or hillside and reflect back to the ears of a listener as an echo. In the same way, some of the pulses of high-frequency radio energy sent out by a radar transmitter from the antenna may strike objects in their path and reflect back to the antenna where a radar receiver detects them. This out-and-back cycle is repeated from 60 to 2,000 times per second, depending upon the design of the set. High-frequency radio energy travels in a straight line only and will not bend with the curvature of the earth. Thus, it is impossible for the wave to strike objects which are beyond the optical horizon. This is known as line-of-sight transmission. If the outgoing wave is sent into a clear sky, very little energy is reflected back to the receiver. The wave and the energy which it carries simply travel out into space and are lost for all practical purposes.

If, however, the wave strikes an object such as an airplane, a ship, a building, or a hill, some of the energy is sent back as a reflected wave. If the object is large and a good conductor of electricity, a strong echo is returned to the antenna. If the object is a poor conductor, or is small, the reflected energy is small and the echo is weak.

Radio Waves

Radio waves of extremely high frequencies travel in straight lines at a speed of 162,000 nautical miles per second as compared to 1,100 feet per second for sound waves. Accordingly, there will be an extremely short time interval between the sending of the pulse and the reception of its echo. It is possible, however, to measure the interval of elapsed time between the transmitted and received pulse with great accuracy—even to one ten-millionth of a second.

The directional antennas employed by radar equipment transmit and receive the energy in a more or less sharply defined beam. Therefore, when a signal is picked up, the antenna can be rotated until the received signal is maximum. The direction of the target is then determined by the position of the antenna.

The echoes received by the radar receiver appear as marks of light on a specially-constructed instrument called the "oscilloscope". This oscilloscope may be marked with a scale of miles, or degrees, or both. Hence, from the position of a signal echo on the oscilloscope, an observer can tell the range and direction of the corresponding target.

3. USES OF RADAR

Modern defense against aircraft attack requires that the presence of hostile planes be made known long before the planes can be seen or heard. This knowledge must be available irrespective of atmospheric conditions; fog, clouds, or smoke during the day or night must not interfere with the detection of hostile aircraft. Radar has provided a source for such information, and at the same time has opened new fields for greatly improving traffic control and safety for both airplanes and ships.

Long-range Reporting

This is done by fixed stations constantly searching a specific area to warn of enemy attack. Information from such stations is recorded continuously. The data are used to guide interceptor craft toward an enemy target.

Gun-laying or Fire Control

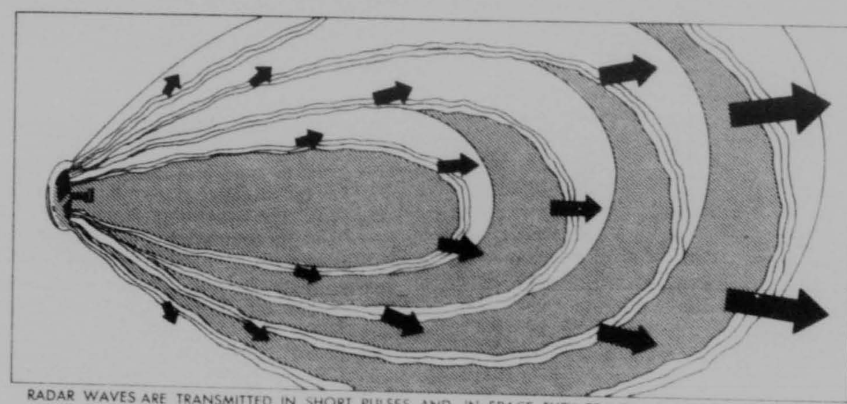
This is the short-range determination of range, azimuth, and elevation of the enemy target for the control of defense equipment, such as search-lights and anti-aircraft batteries. Such bearings must be made rapidly and accurately.

Air- or Ship-borne Use

Portable equipment is used in patrol craft to search for the presence of enemy craft, and in combat craft to locate the target, and for fire control. The equipment may be designed for the detection and location of cities, rivers, bridges, aircraft, surface vessels, or surfaced submarines. It may also be used as an aid to navigation by a ship or plane to determine its course or position in relation to ground targets or a home beacon station. Air-borne equipment is used in night fighter aircraft to locate and to destroy enemy aircraft. Air-borne radar equipment is used also to identify friendly ships to fighter command to distinguish them from the enemy.

4. HISTORICAL DEVELOPMENT

One of the first observations of "radio echoes" was made in the United States in 1922 by Dr. Albert H. Taylor of the Naval Research Laboratory. Dr. Taylor observed that a ship passing between a radio transmitter and receiver reflected some of the waves back toward the transmitter. Between 1922 and 1930 further tests proved the military value of this principle for the detection of surface vessels which were hidden by smoke, fog, or darkness. Further developments were conducted with carefully guarded secrecy. During this same period Dr. Breit and Dr. Tuve, of the Carnegie Institute, published reports on the reflection of pulse transmission from electrified layers in the upper atmosphere which forms the earth's ceiling. This led to the application of the principle to the detection of aircraft. Other countries carried on further experiments independently and with the utmost secrecy. By 1936, the United States Army was engaged in the development of a radar-warning system for coastal frontiers. Between 1936 and 1940 the pulse system of transmission was further developed. By the end of 1940 mass production of radar equipment was under way. By September 1940, the



RADAR WAVES ARE TRANSMITTED IN SHORT PULSES AND, IN SPACE, THEY TRAVEL TO INFINITY. A SYMBOLIC CROSS-SECTION OF THESE PULSES IS SHOWN ABOVE. THE ARROWS INDICATE THE DIRECTION THEY ARE TRAVELING AWAY FROM THE REFLECTOR.

Figure 6—1. Radar Pulses in Space.

British had developed radar to such a point that they were able to bring down great numbers of enemy planes with little loss to themselves. Beginning in 1941, British-American cooperation in the development of radar has given the United Nations the best radar equipment in the world. The Germans also made great strides in radar development. This was evidenced by the sinking of the British battle-cruiser Hood by the German battleship Bismarck, by means of radar finding, before the Hood could fire her second salvo.

5. BASIC RADAR

In the applications of radar, three elements are of primary interest, namely, the range, azimuth, and altitude of any given target. Therefore, equipment must be designed so that range, azimuth, altitude, or any combination of the three can be determined.

Range Measurement

The measurement of range will be considered first. Radio waves travel at a known velocity of approximately 162,000 nautical miles per second. For a radio wave to travel one nautical mile, therefore, would take 6.2 microseconds. (A microsecond is one-millionth of a second.) For a radio wave to travel one nautical mile to a target and return would require 12.4 microseconds. In radar the time required for a radio wave to travel one mile to a target and return is called a "range mile" in time. Now, if a device is incorporated in the equipment to measure the time required for a pulse to travel to a target, be reflected, and return, the range can be measured directly. In other words, instead of calibrating the range scale in time, it is calibrated with mile marks every 12.4 microseconds.

Transmitted Radio Energy

To determine azimuth and relative altitude, the radio energy must be transmitted in only one direction at any given instant. To do this, a highly-directional transmitting and receiving antenna is used. The directional antenna acts like a nozzle on a hose, so that the radio energy can be directed in any direction desired. Now, if two protractors are placed on the directional antenna, one on a horizontal plane and one on a vertical plane, the position in which the antenna rests at a given instant can be measured. This would indicate the azimuth and the elevation of the object reflecting the transmitted energy. The directional antenna allows the use of a low-power transmitter because all its energy can be concentrated on a small area.

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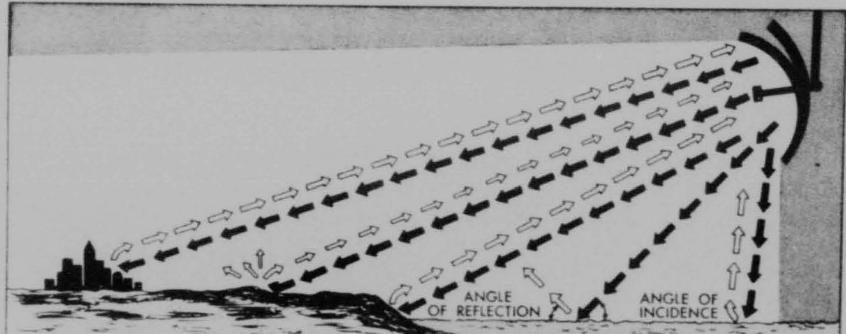
6. PULSE TECHNIQUE

Most radar systems utilize the pulse technique of transmission of radio energy. By this method extremely short, powerful, pulses of radio energy are transmitted at regular intervals. The time duration of the pulse is one-half to two and one-half microseconds with a peak power of 50 to 150 kilowatts. The pulses are transmitted at frequencies ranging from 60 to 2,000 pulses per second. Pulsing provides an easy way to measure range since the transmitted pulses can be used as starting points for measuring range. Pulsing is necessary to measure range in order to distinguish which echo is being received. The idea is to send out a pulse of energy and start measuring time until a reflection or echo is received. The time which elapses between the transmitter pulse and the received echo will determine the range. Then another pulse will be sent out and the same procedure will be repeated. To search for targets over a wide range in azimuth, the directional antenna is rotated so that it can transmit radio energy in the direction desired. (Figure 6-2.)

Pulsing

Pulsing also has its limitations. To concentrate energy on a given area often enough, as the antenna rotates, to give a good, clear return from the target, the pulses must be transmitted at a high-repetition frequency. If the pulses are transmitted too often, however, the range of the equipment is limited by not allowing enough time for the long-range echoes to return before another pulse is transmitted. For instance, suppose pulses were transmitted at a rate of 1250 per second. This would allow only 800 microseconds between pulses, so only targets up to a range of $\frac{800}{12.4}$ or 64 miles approximately could be received. Thus, it can be seen that a compromise must be struck between range and pulse-repetition rate.



WHEN A RADAR PULSE STRIKES A SURFACE, THE ANGLE OF ITS REFLECTION IS EQUAL TO THE ANGLE OF INCIDENCE. AN ECHO IS REFLECTED BACK TO THE RECEIVER, THEREFORE, ONLY WHEN THE ANGLE OF INCIDENCE IS 90°. SINCE THE RADAR INDICATIONS OR SCOPE PICTURE DEPENDS UPON THE STRENGTH OF RECEIVED ECHOES, ONLY THOSE OBJECTS WHOSE SURFACES ARE 90° TO THE LINE OF TRAVEL OF OUTGOING PULSES WILL BE VISIBLE. SIZE AND CONCENTRATION OF SUCH SURFACES DETERMINE STRENGTH OF ECHOES AND, HENCE THE SIZE AND CLARITY OF OBJECTS ON THE SCOPE PICTURE. IN THE SCHEMATIC DRAWING ABOVE, SOLID ARROWS REPRESENT THE LINE OF TRAVEL OF THE OUTGOING PULSES AND SHADED ARROWS, REFLECTION OF PULSES BY VARIOUS TYPES OF OBJECTS.

Figure 6—2. Reflection of Radar Pulses.

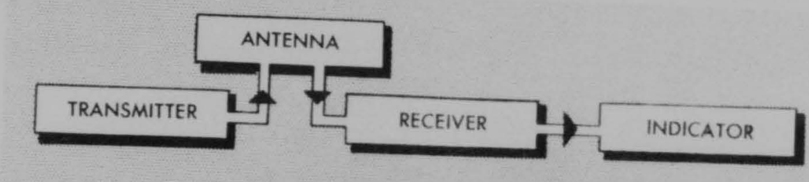


Figure 6—3. Block Diagram of a Simple Radar System.

7. THE PLAN POSITION INDICATOR (PPI)

A basic radar system consists of the following components: transmitter, receiver, antenna, and indicator. See Figure 6-3 and Figure 6-4.

Transmitter

The transmitter generates a high-power, ultra-high frequency pulse which is radiated by the antenna.

Receiver

Reflection or echoes are received by the same antenna and fed into the receiver. The receiver acts as an ordinary broadcast receiver in that it detects the return echoes and converts them into voltage pulses. Consequently, instead of feeding the received signals into a loudspeaker so they can be heard, the signals are fed into the indicator unit where they can be seen visually on a cathode-ray tube screen.

Antenna

A radar system can use a single antenna for both transmission and reception because transmission is necessary only during the short initial pulse. This is accomplished by using a switch in the antenna feed line, so that either the transmitter or the receiver is connected to the antenna at any given instant. The switch is referred to as the Transmit-Receive, or T-R box and is operated electronically.

Indicator

The indicator units are essentially a cathode-ray tube with its associated circuits. The cathode-ray tube is a special type of vacuum tube in which electrons emitted from a cathode are caused to move at a very high velocity, are formed into a narrow beam, and are then allowed to strike a chemically-prepared screen which fluoresces, or glows, at the point where the electron beam strikes. The importance of the cathode-ray tube is that it provides a visual means of examining the signal-return voltages which are reflected into the receiver unit. Because electrons are so very light in weight, the electron beam can be deflected very quickly. This property enables the cathode-ray tube to be used in measuring currents and voltages in terms of millionths of a second.

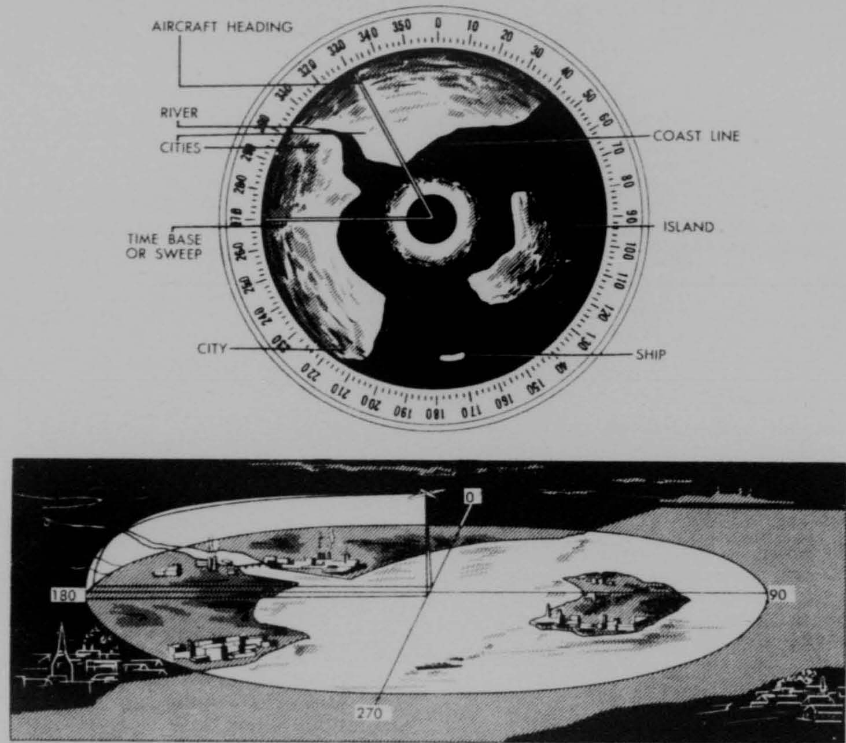
8. CATHODE-RAY TUBES

There are two general types of cathode-ray tubes: electrostatic and electromagnetic. These types refer to the method used to introduce the signal voltages into the tube and to focus the electron beam.

Electromagnetic and Electrostatic Tubes

In the airborne equipment, the magnetic deflection type of cathode-ray tube is used in preference to the electrostatic deflection type. The advantages of the electromagnetic tube are its greater structural simplicity, its greater ruggedness, and its shorter length for a given size screen.

The electromagnetic type of cathode-ray tube has come into recent use because of the greater definition possible with magnetic focusing. Also, electromagnetic deflection has a number of advantages over electrostatic deflection, particularly when a rotating radial sweep is required to give polar indications as in the case of Plan Position Indicator, or PPI, type of presentation.



IN THE PERSPECTIVE DRAWING ABOVE, THE RADAR BEAM IS SWEEPING THROUGH 360 IN AZIMUTH. THE SCOPE PICTURE OF THE AREA SCANNED IS PRESENTED AT THE TOP. NOTE THAT THE SWEEP ON THE SCOPE ALWAYS IS IN STEP WITH THE RADAR BEAM. HERE BOTH ARE AT 270.

Figure 6–4. The Radar Beam in Action.

Referring to Figure 6-5, electrons are emitted by the cathode. A control grid surrounds the cathode and acts as a valve to control the number of electrons passing toward the screen. The control grid thus controls the intensity of the beam. Incoming signals are converted into a series of voltage pulses fed to this grid. Each voltage pulse allows more electrons to flow which intensifies the electron beam during the time of the pulse and produces a bright spot on the cathode-ray tube screen. The negatively-charged electrons are attracted by the positively-charged first anode. Some of the electrons pass through a hole in the first anode toward the screen. The focus coil of an electromagnetic tube is wound on an iron core which may be moved along the neck of the tube to a limited extent to focus the beam. The magnetic field created by the focusing coil tends to form the electrons into a fine point as they strike the screen. The deflection coils also make use of the magnetic field to produce the sweep in the indicator. The deflection coils are so wound that a changing current through them causes a deflection of the electron beam from the center of the PPI screen to the outside rim. By rotating the deflection coils around the neck of the

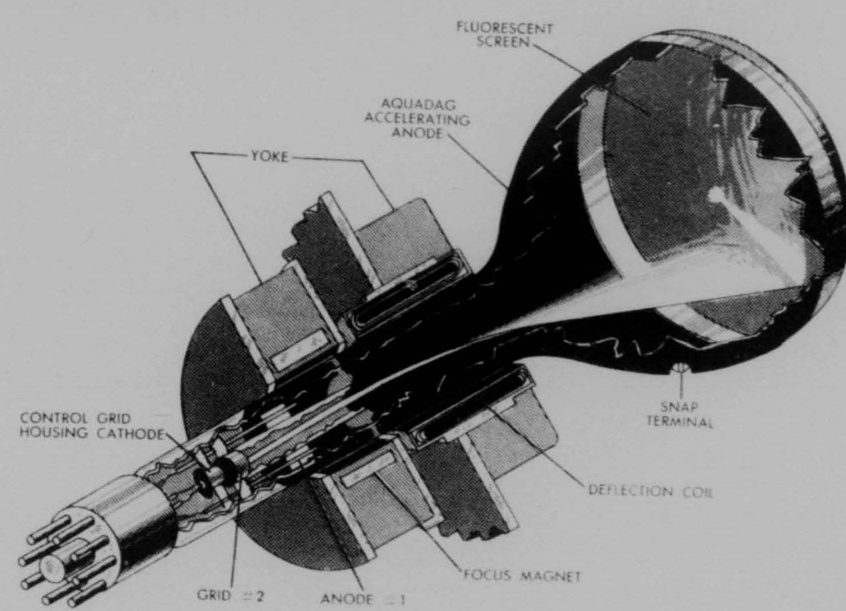


Figure 6–5. Electromagnetic Cathode-Ray Tube.

tube, we can thus create a radial sweep on the PPI screen. The second anode is called the "Aquadag accelerating anode" in this tube. The inside of the tube is covered with a compound of graphite known as "aquadag" and a high positive voltage is placed on it to accelerate the electrons toward the screen. The screen of the tube is coated with a chemical which fluoresces when struck by electrons.

An electron beam consists of a large number of electrons moving with high velocity and possessing considerable kinetic energy. This energy of motion is transformed into energy of other forms when the electron beam strikes some object. If the object is coated with a fluorescent chemical, part of the energy is transformed into light. Most of the energy, however, is dissipated in heat. If the electron beam is concentrated in one spot for a considerable length of time, it will destroy the fluorescent chemical and possibly even melt the glass tube. The operator is cautioned to guard against this condition.

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SECTION II—GENERAL DESCRIPTION, FUNCTION, AND PRINCIPLES OF OPERATION OF A/N APQ 13-2 & 23-2

1. FUNCTION OF BASIC RADAR SET APQ-13

The primary purpose of the AN APQ-13 is to serve as a high-altitude bombing set during overcast weather conditions. Because of insufficient definition, its results cannot be classified as precision bombing but rather as area or pattern bombing. When used in conjunction with the Norden bombsight, its accuracy is greatly improved.

In addition to its use as a bombing set, it is a valuable navigational aid. By observing the PPI scope, it is possible to determine the direction and velocity of the wind, and the speed and altitude of the plane. In operating the set with azimuth stabilization (the output of the flux-gate compass system of the plane is fed to the APQ-13), true north appears at the top of the scope at all times regardless of the plane's movement.

Navigation is also aided by the set's ability to trigger off a beacon up to 300 miles distance enabling the navigator to take a fix or home on the beacon.

In addition to all these uses, it can be used as a conventional sea-search set to detect targets.

It can be readily seen that the AN APQ-13 is an all-round radar set and not exclusively a bombardment set.

2. FACTORS INFLUENCING FALL OF BOMB

If a bomb were released from a plane and no air resistance existed, it would fall at the same forward velocity as the speed of the plane and be directly below the plane at the moment of impact. But since air resistance does exist, holding the bomb in the air longer (vertical lag), and reducing its forward speed (horizontal lag), the plane may be a considerable distance ahead of the point of impact. This distance is called trail.

From this very brief discussion, it is obvious that the altitude of the aircraft will affect the vertical lag in the fall of the bomb, that the speed of the plane will affect the horizontal lag, and that the particular type of bomb will affect the air resistance. Therefore, the three factors influencing the fall of a bomb are altitude, speed, and bomb-type.

Crosswind will also alter the path of the falling bomb—the point of impact will be either to the left or right of the plane's track. The distance from the track to this point is called crosstrail. No correction is made for crosstrail on this equipment. It should be remembered that all computers must take altitude, speed, and bomb-type into consideration.

3. BOMBING TECHNIQUES

There are three methods of sighting: optical sighting with the telescope in the Norden bombsight, radar sighting by observing the target on the scope, and synchronous sighting with the radar set supplying the sighting information to the Norden computer. (This also is called coordinated visual sighting.)

Optical Sighting (Norden Bombsight)

Two indexes appear on the Norden bombsight. One represents a predetermined dropping angle (angle made between a perpendicular and the telescope pointing to the target). The other index represents the instantaneous sighting angle. As the plane approaches the target, the sighting angle should keep decreasing at a rate proportional to the speed of the aircraft until the sighting angle equals the dropping angle. When the sighting angle equals the dropping angle, the bombs are released.

Figure 6—6. Plan Position Indicator (PPI).

The rate of closure (closing in on target) is determined by the movement of the telescope. A motor turns the telescope at a speed decided upon by the bombardier as he keeps the target on the telescope crosshairs.

Radar Sighting (AN/APQ-13)

In radar-sighting, release-line method, a slant-range bomb-release chart is used. The primary function of this chart is to determine the instant the bombs should be released so that they will hit the target. In addition to the horizontal lines representing altitude are the vertical lines representing various true ground speeds.

To determine the point of bomb release, the operator goes through the following procedure:

By rotating the altitude knob, the operator will set the horizontal crosshair of the slide directly on the plane's radar altitude, as indicated on the altitude scale of the chart. He will then rotate the range knob until the intersections of the crosshair on the slide lie directly over the ground-speed line corresponding to the true ground speed of the plane. These two adjustments of the computer predetermine the position of the bomb-release circle on the face of the PPI. The proper instant to release the bombs will come when the target to be bombed just passes under the bomb release circle.

Synchronous Sighting (Norden and Radar). (Coordinated Visual)

A synchronous bomb-release chart is used. The primary function of this chart is to determine specific sighting angles, ranging from 70 to 21 degrees, from the plane to the target. It is used also to determine the slant range of any target. It is used also to determine the slant range of any target within 15 miles and to determine radar altitude as with the slant-

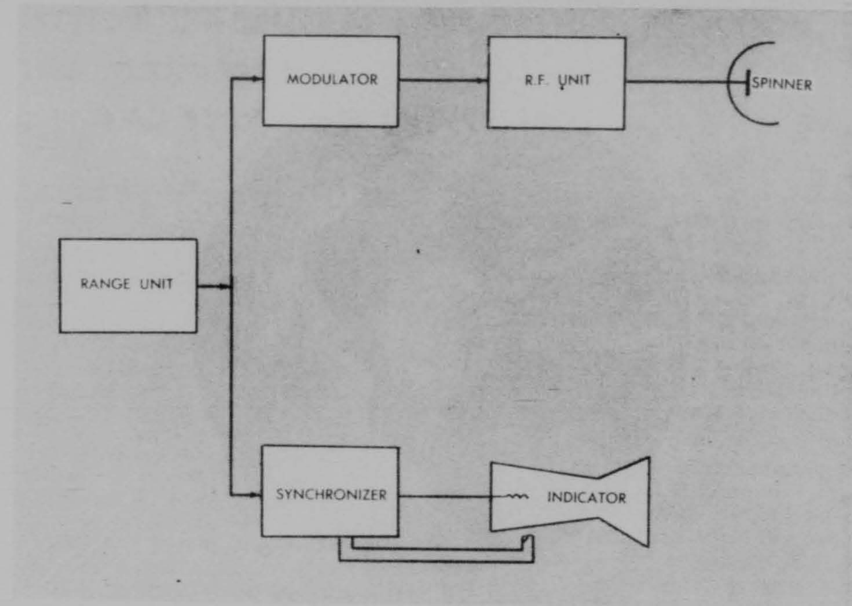

Figure 6–7. Block Diagram, Radar Set.

range bomb-release chart. In addition to horizontal lines representing altitude and vertical lines representing slant range, there is a group of eleven diagonal lines representing various sighting angles from 70 to 21 degrees.

In practice, the radar operator sets up the bomb-release circle by setting the computer drum at the intersection of the appropriate horizontal altitude line and the largest sight-angle line appearing on the altitude line. He notifies the bombardier, via interphone, what that sighting angle is. The bombardier has already preset his dropping angle form rate, trail, disc speed, etc., and he now sets in the sighting angle supplied by the radar operator.

When the target coincides with the bomb-release circle at this setting, the radar operator informs the bombardier, who starts his rate motor (motor-driving telescope). In the meantime the operator has reset his computer to the next lowest sighting angle and as the target approaches coincidence with the new setting of the bomb-release circle, the radar operator calls to the bombardier, e.g. "68 degrees—now!" As this signal is given, the bombardier notes the angle to which the sight has moved at this instant, and if it varies from the value given by the radar operator, he makes an appropriate change in the rate and displacement of the bombsight. This process is continued for other angles as the release point is synchronized for rate and range.

As in normal visual bombing, the bombs are released automatically by the sight when the release point is reached. As an added precaution, the radar operator sets up his equipment for slant-range bombing and follows through on the run so as to be able to take over in case of bombsight failure. It is necessary, as in release-line bombing, for the radar operator to supply the pilot with appropriate course corrections during the bomb run.

Overall Operation of Radar Set

The radar set begins with a master timer (in range unit) which simultaneously trig-

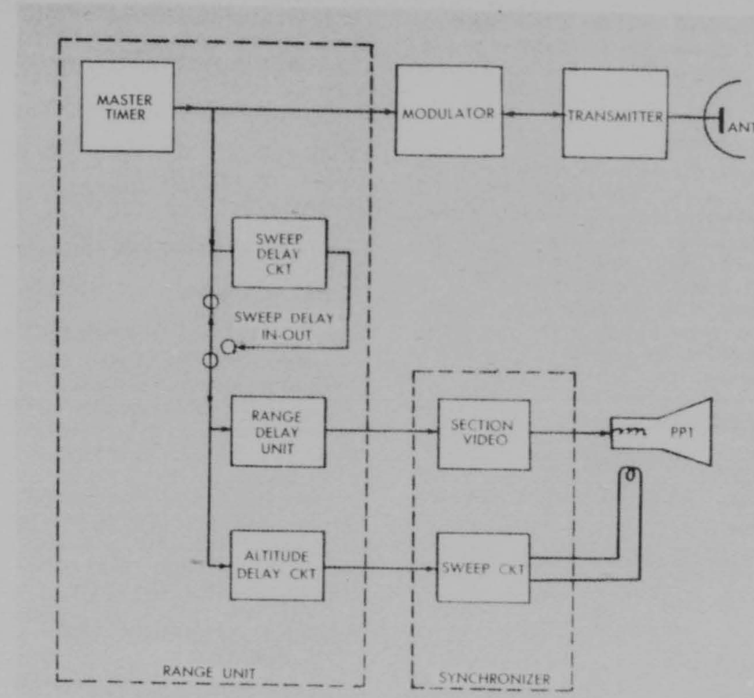

Figure 6–8. Block Diagram, Timing CKT.

gers the transmitter through the modulator and RF unit and starts the sweep in the synchronizer unit. The received signal comes from the antenna (spinner) through the preamplifiers in the RF unit and receiver (in synchronizer) to the PPI (in indicator). Figure 6-6 shows this simple basic function. (See Figure 6-7.)

4. PRINCIPAL CHANNELS OF RADAR SETS

Every radar set can be broken down into a minimum of five channels, namely: transmitter, receiver, sweep, Selsyn and power-supply channels. For simplification in study and rapid trouble shooting, the set will be presented by channels rather than by units. Thus the continuity of the electrical circuits will be maintained regardless of the number of units involved. (See Figure 6-8.)

Transmitter Channel

The pulse which eventually triggers the transmitter magnetron comes from the master timer circuit located in the range unit. The modulator simplifies and shapes the pulse and feeds it to the magnetron transmitting tube. An intense pulse of high frequency is then transmitted to the antenna (spinner) through a flexible waveguide.

Receiver Channel

The reflected energy is picked up by the same antenna and returned to the converter in the RF unit (which includes the beating oscillator and two stages of IF preamplifica-

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tion). The signal from the IF preamplifier is then fed through the remainder of the receiver located in the synchronizer unit and finally to the CRT in the indicator unit.

Sweep Channel

The master timer in the range unit which triggers the transmitter also initiates the sweep. However, the pulse must pass through the altitude-delay circuit and possibly through the sweep-delay circuit (depending upon whether sweep delay is being used) all in the range unit. From the range unit, the pulse starts the sweep circuit in the synchronizer unit. The sweep then appears on the CRT in the indicator.

Selsyn Channel

The Selsyn system must convert a physical rotation of the antenna into electrical energy and transmit this energy to the point desired (indicator) and reconvert it to a physical rotation of the sweep. The Selsyn phasing units, torque amplifier, and the azimuth control box aid in orienting the sweep and antenna position.

Power Supplies

No central power supply exists for this set. In addition to the low-voltage rectifier and high-voltage rectifier, the range unit, modulator and torque amplifier have additional power supplies.

Set Characteristics

Transmitter frequency: 9375
Wavelength: 3 cm.
Intermediate frequency: 60 mc.
PRF on 4-, 10-, 20-mile radar: 1350 C.P.S.
PRF on 50-, 100-mile radar: 675
PRF on all beacon ranges: 270
Pulse width on 4-, 10-, 20-mile radar:
MD-12 MD-38
½ ms ½ ms.
Pulse width on 50-, 100-mile radar:
1⅛ ms ¾ ms.
Pulse width on all beacon ranges:
2¼ ms 2¼ ms.
Peak Power output: 40 KW Average Power output—30 Watts.
Beacon frequency: 9310 mc.
Altitude limits: 15,000 to 35,000 feet.
Tx radiation width in degrees: 3.
Antenna tilt limits: Plus 10 degrees, minus 30 degrees.
Sector scan limits in degrees: 50° plus or minus 10°.
Spinner speeds: continuous 20 to 27 RPM cw-ccw 13 to 21 RPM
Sector scan 13 to 21 RPM, or 50-60 scans per minute.
Units that are pressurized: R.F., Top Hat, wave guide.
Amount of pressure: 5 to 7 pounds per sq. in. —med. to RF unit.
Range mark spacing: 1 and 5 miles.
Crystal current: .5 to 1.2 ma.
Transmitter current: 6 to 8 ma.
Approximate weight of equipment: 630 lbs.
Altitude delay limits: 3 to 5 miles.
Range delay limits: .5 to 15 miles.
Sweep delay limits: 0 to 200 miles.
Antenna radiation pattern: Cosecant Sq.
Average power used: 8 amps, 27½ volts DC; 10.4 amps, 115 volts AC.
Average inverter drain: 100 amps at 27.5 volts DC with a starting drain of 700 amps.

5. APQ-23 COMPUTER AND ITS PURPOSE

To understand the bombing equations solved by the APQ-23 computer, it is necessary to recall a few of the basic mathematical operations. In this chapter, the principles of algebra, geometry, and trigonometry, which are pertinent to offset bombing are reviewed and explained. A careful study of this material will help follow the development of the bombing equations and their application.

Algebraic Manipulations

An algebraic expression is one that expresses or represents a number by signs, numerals, letters, and exponents. It may consist of a single letter, such as E (for voltage); it may be two letters, such as IR (I times R, or current times resistance); it may contain an exponent, as in I^2R (I squared times R, or current squared times resistance); or it may contain a variety of factors, such as $5x^2Y$ (5 times x squared times y). The value of the number represented depends on the value of the letters. Thus, if I is 5 and R is 100, IR is

500; while if I is 2 and R is 50, IR is 100. The arrangement of the numerals and the letters indicates whether they are to be multiplied or divided; for example, ab means a times b, $\frac{a}{b}$ means a divided by b. The sign indicates whether the number is to be added or subtracted. Sometimes, of course, the final product has a negative sign when there is nothing from which to subtract. One should not be disturbed by that fact. It merely indicates a negative reference such as one encounters in a negative voltage.

Algebraic Expressions

Algebraic expressions can be treated as numbers, that is, they can be added, subtracted, multiplied, and divided. Two or more expressions can be multiplied by writing them as one expression; for example, ab times cd is written abcd. Similarly, abcd divided by bc equals ad. Two or more expressions may be added or subtracted only if they are like quantities, that is, have the same letters raised to the same powers. Thus, 5x plus 6x equals 11x. However, 5x plus 6y cannot be combined in one term because they have different letters. Enclosing expressions with parentheses ( ), brackets [ ], or braces { }, means that the enclosed terms are to be considered as one quantity; for example, the expression 16 − (12 − 6) means that the quantity (12 − 6) is to be subtracted from 16; the result is 10.

6. ALGEBRAIC OPERATIONS AND THEIR ORDER

In performing a series of different operations, some order must be followed. It has been agreed that multiplication and division must be performed first, and then addition and subtraction.

Example

$16 \div 4 + 8 + 4 \times 5 - 3$
$= 4 + 8 + 20 - 3$ (dividing and multiplying)
$= 32 - 3 = 29$ (adding and subtracting)

Addition

To add quantities with like signs, add their absolute values and prefix the common sign.

Example

Addition of Numbers

+6	+3	−6	−3
+3	+2	−3	−2
+9	+5	−9	−5
	+10		−10

Addition of Like Terms

+4Ra	+2Ra	−4Ra	−2Ra
+2Ra	+5Ra	−2Ra	−5Ra
+6Ra	+Ra	−6Ra	−Ra
	+8Ra		−8Ra

Addition of Unlike Terms

+4Ra	−3H
+6H	−6Ra
+3Rn	−4Rn
+4Ra +6H +3Rn	−3H −6Ra −4Rn

Addition of Polynomials

(Expressions of 2 or more terms)

+4Ra +6H +3Rn	−4Ra −6H −3Rn
+6Ra +2Rn	−6Ra −2Rn
+2H +7Rn	−2H −7Rn
+10Ra +8H +12Rn	−10Ra −8H −12Rn

To add quantities with unlike signs, find the differences of their absolute values and prefix to the result the sign of the one that has the greater absolute value.

Example

Addition of Numbers

+6	+3	−6	−3
−3	−2	+3	+2
	+5		−5
+3		−3	
	+6		−6

Addition of Like Terms

+4Ra	+6H	−4Ra	−6H
−2Ra	−2H	+2Ra	+2H
	−3H		+H
+2Ra		−2Ra	
	+H		−3H

Note that in the second example, the result is written as +H (not +1H). The numeral 1 is never written in front of an algebraic expression.

Addition of Unlike Terms

$-4Ra$	$+4Ra$
$+6H$	$-6H$
$-3Rn$	$+\ Rn$
$-4Ra+6H-3Rn$	$Rn-6H+4Ra$

Note that there is no sign in front of Rn in the second example. No sign is put in front of the first term of a series unless the term is negative, as in the first example.

Addition of Polynomials

$-4Ra+6H-3Rn$	$+4Ra-6H+3Rn$
$-2H+2Rn$	$+2H-2Rn$
$+6Ra-6Rn$	$-6Ra+5Rn$
$2Ra+4H-7Rn$	$-2Ra-4H+6Rn$

Subtraction

To subtract quantities from each other, change the sign of the quantities to be subtracted and add all the quantities in accordance with the rules of addition.

Example

$+8-(+3)=8-3=5$

$+8-(-3)=8+3=11$

The rule for this procedure is sometimes put as the following rule of grouping: to remove parentheses or other symbols of grouping preceded by a minus sign, change the sign of every term that was included in the group.

Example

$(-9a+5b)-(-10b+6a-3b)$

$=-9a+5b+10b-6a+3b$

$=-15a+18b$

Parentheses or other symbols of grouping preceded by a plus sign may be removed without any other change.

Example

$(x+y)+(2x-4y)$

$=x+y+2x-4y$

$=3x-3y$

Multiplication

Two or more expressions may be multiplied by writing them as one expression; for example, ab times cd is written as abcd. When either of the expressions to be multiplied contains more than one term, multiplication is indicated by putting expressions in parentheses next to each other; for example, ab times c + d is written as (ab) (c + d).

In multiplying expressions with different signs, determine the sign of the product by the number of negative factors. If there is an even number of negative factors, the product is positive; if there is an odd number of negative factors, the product is negative.

Example

$(-a)\ (-b)=ab$

Even number of negative factors.

$(-a)\ (+b)=-ab$

Odd number of negative factors.

$(a)\ (-b)=-ab$

Odd number of negative factors.

$(-a)\ (-b)\ (-c)=-abc$

Odd number of negative factors.

$(-a)\ (-b)\ (-c)\ (-d)=abcd$

Even number of negative factors.

Division

When quantities are divided, the quotient is positive if the numbers have like signs and negative if the numbers have unlike signs.

Examples

$\frac{6}{3}=2 \qquad \frac{-6}{-3}=2 \qquad \frac{-6}{3}=-2 \qquad \frac{6}{-3}=-2$

Equations

An equation is a mathematical statement that two or more expressions are equal to each other; for example, the equation e + 3 = 7 states that when 3 is added to e, the total is 7. Solving an equation is finding the value of the literal numbers in the equation. In the equation just given, it is easy to see that e equals 4. However, there are many equations which are far more difficult to solve. These require various types of manipulation for their solution. These manipulations are based chiefly on axioms. An axiom is a statement which is obviously true and is accepted without proof. The following axioms will help solve equations: If equal numbers are added to or subtracted from both sides of an equation, its equality is not destroyed.

Example

If $x=y$

Then $x+2=y+2$ and $x-2=y-2$.

Both sides of an equation may be multiplied or divided by the same number without destroying the equality.

Example

If $x=y$

Then $5x=5y$ and $\frac{x}{5}=\frac{y}{5}$

Numbers that are equal to the same numbers are equal to each other.

Example

If $x=a$ and $y=a$

Then $x=y$

A few other rules and processes which have grown out of axioms are helpful in solving equations. These include transposition, changing signs, and cancellation.

A term may be transposed from one side of an equation to the other, provided its sign is changed.

Example

Solve for x in the following equation:

$x-3=2;\ x=2+3=5$

(The 3 was transposed from the left side to the right side of the equation and its sign was changed.)

If the same term with the same sign occurs on both sides of the equation it may be eliminated from both sides.

Example

Solve for x in the following equation:

$x+y=2+y$

Cancelling y, $x=2$

The signs of all the terms of an equation may be changed without destroying equality.

Example

Solve the equation	$8-x=3$
Transposing:	$-x=3-8$
Changing signs	$x=-3+8=5$

Transposition may also be accomplished by multiplication and division.

Examples

Solve for R in the equation $E=IR$

Dividing both sides by I, $\frac{E}{I}=\frac{IR}{I}$

$R=\frac{E}{I}$

Solve for c by multiplying both sides by c:

$1=\frac{1}{2ac} \qquad c=\frac{c}{2ac} \qquad c=\frac{1}{2a}$

If there is any doubt about the solution of the equation, the solution may be checked by substituting the values in the original equation. If the equation holds true, the solution is correct.

Examples

$3x+14+2x=x+26$

Transposing: $3x+2x-x=26-14$

Adding terms: $4x=12$

$x=3$

Test by substituting 3 for I in the original equation.

$3x+14+2x=x+26$

$(3\times3)+14+(2\times3)=3+26$

$9+14+6=29$

$29=29$

The equation is checked and the solution is correct.

7. PLANE GEOMETRY

A review of the basic concepts of plane geometry that apply to the various bombing problems will help understand the solution of these problems. Since most of the problems deal with right triangles and parallel lines they are reviewed here.

One of the basic elements of geometry is the angle. An angle is the figure formed by two straight lines drawn from the same point. The size of an angle depends upon the amount one of the lines must rotate about the point to coincide with the other line. In the illustration of angles, the size of the angle depends upon the amount the line AB must revolve about B to take the position CB. The size of the angle does not depend on the length of the sides. The two angles in the drawing are the same size even though their sides differ in length.

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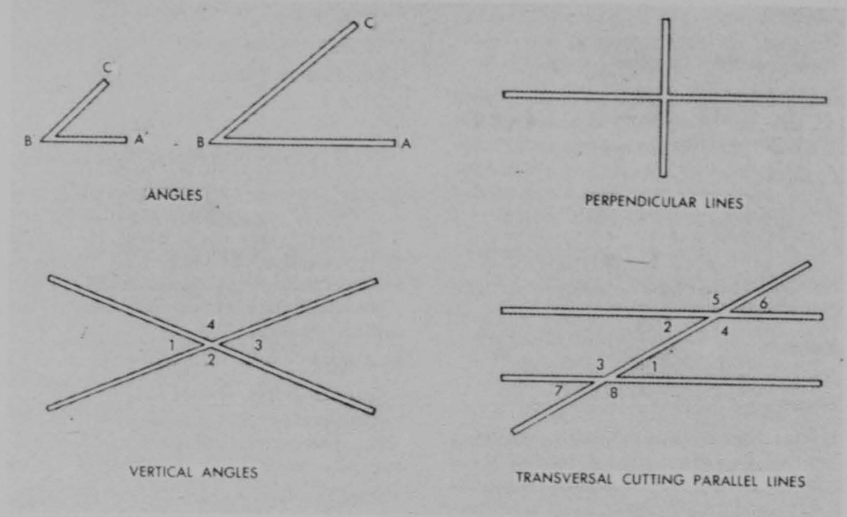


Some Basic Elements of Plane Geometry

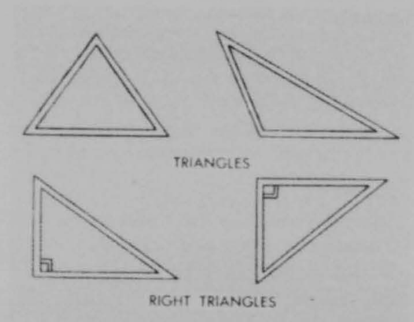
If four equal angles are formed when one straight line intersects another, the angles are called right angles. Because one complete revolution of a line about a point is equal to 360 degrees, the sum of four right angles is equal to 360 degrees and each right angle is equal to 90 degrees. The two lines forming the right angles are called perpendicular lines.

The two pairs of opposite angles formed by the intersection of two straight lines are called vertical angles. Thus, angles 1 and 3 and 2 and 4 in the diagram are vertical angles. Geometry proves that vertical angles are equal. Remember this fact, for it will be helpful in understanding the drift angle in bombing problems.

Parallel lines are lines that do not meet, no matter how far they are extended. If parallel lines are cut by a transversal (a straight line across them), they form alternate interior angles on opposite sides of the transversal between the parallel lines. It is proven by geometry that alternate interior angles are equal. Thus, in the drawing, angle 1 is equal to angle 2, and angle 3 is equal to angle 4. This relationship is useful in understanding angle Dc in the bombing problem. The angles formed on the outside of parallel lines cut by a transversal are called alternate exterior angles. Alternate exterior angles are also equal. Thus, angle 5 is equal to angle 8, and angle 6 is equal to angle 7.

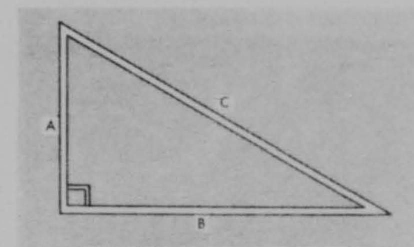
8. TRIANGLES

A figure bounded by three straight lines is called a triangle. A triangle that contains a right angle is a right triangle. The side opposite the right angle is called the hypotenuse.



Pythagoras, a famous Greek philosopher and mathematician who lived about 540 B.C., proved that in any right triangle, regardless of size, the square of the hypotenuse is equal to the sum of the squares of the other two sides. This is known as the Pythagorean theorem, and in mathematics is usually written as follows:

$a^2 + b^2 = c^2$



PYTHAGOREAN THEOREM: A² B² C²

This theorem has many uses in the bombing problem. It is used, for example, to find the straight-line distance from the plane to the target when the altitude and ground range are known. Consider a situation where the altitude is 4 miles and the ground range is 3 miles. The straight-line distance from the plane to the target forms the hypotenuse of the triangle. According to the Pythagorean theorem:

$c^2 = a^2 + b^2$

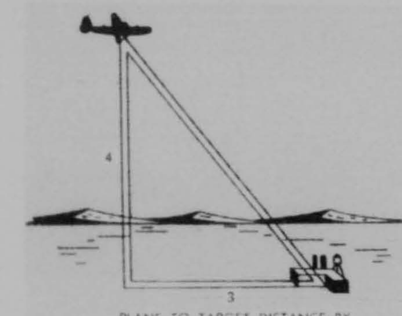
Substituting the values in the equation, it becomes:

$$c^2 = 4^2 + 3^2$$
$$= 16 + 9$$
$$= 25$$
$$c = 5$$

The straight-line distance from the plane to the target is 5 miles.

9. TRIGONOMETRIC FUNCTIONS

In any right triangle there is a definite relationship between the size of the acute angles (the angles that are not right angles), and the length of the sides. This relationship forms the foundation of trigonometry. There are three relationships between the size of an angle and the size of the sides of the triangle which one will find particularly important in



PLANE TO TARGET DISTANCE BY PYTH. THEO. √4² 3²

study of the bombing problems. These are the sine, the cosine, and the tangent. They are known as trigonometric functions.

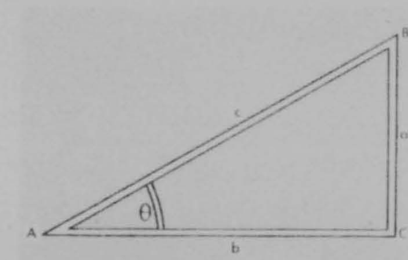
In the triangle shown, the relationships are as follows:

The sine of angle θ (written sin θ) $= \frac{a}{c} = \frac{\text{opposite side}}{\text{hypotenuse}}$

The cosine of angle θ (written cos θ) $= \frac{b}{c} = \frac{\text{adjacent side}}{\text{hypotenuse}}$

The tangent of angle θ (written tan θ) $= \frac{a}{b} = \frac{\text{opposite side}}{\text{adjacent side}}$

The value of the trigonometric functions can be calculated when needed. However, to speed up computation, mathematicians have calculated the values and have prepared tables



Illustrating the Trigonometric Functions

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of these functions. These tables are known as tables of natural functions to distinguish from tables of the logarithms of the functions.

Here are a few problems to illustrate the use of trigonometric functions:

The hypotenuse of a right triangle is 10 inches long, and one side is 5 inches. Find the size of the angles and the length of the other side of the triangle.

To find angle θ, the sine function can be used.

$$\text{Sin } \theta = \frac{\text{opposite side}}{\text{hypotenuse}}$$

Substituting: $\text{Sin } \theta = \frac{5}{10} = .500$

Referring to the tables, you find that the angle whose sine is .500 is 30°.

Therefore, $\theta = 30°$

To find angle ⌀, the cosine function can be used.

$$\text{Cos } \emptyset = \frac{\text{adjacent side}}{\text{hypotenuse}}$$

Substituting: $\text{Cos } \emptyset = \frac{5}{10} = .500$

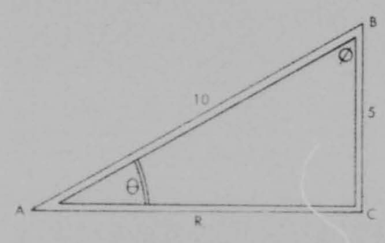
From the trigonometric tables you will find that an angle whose cosine is .500 is 60°. Therefore, ⌀ = 60°. To find the other side (Ra), the cosine function can be used.

$$\text{Cos } \theta = \frac{\text{adjacent side}}{\text{hypotenuse}}$$

Substituting: $\text{Cos } \theta = \frac{\text{Ra}}{10}$

Cross-multiplying: $\text{Ra} = 10 \text{ Cos } \theta$

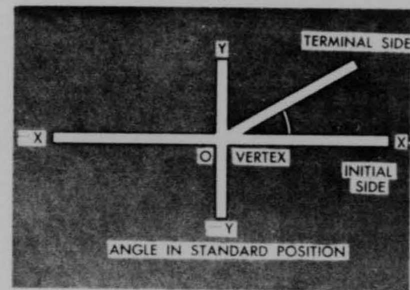
From the trigonometric tables, you will find that the cosine of a 30° angle is .866; therefore, Ra = (10) (.866) = 8.66 inches.



Use of the Trigonometric Functions

Functions of Angles Larger Than 90 Degrees

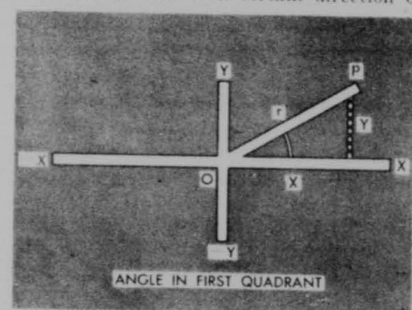
An angle can be considered as generated by a line that starts in a certain initial position and rotates about a point until it stops at its final position. The point is called the vertex of the angle. The original position of the rotating line is called the initial side of the angle, and the final position is called the terminal side of the angle.



ANGLE IN STANDARD POSITION

An angle is said to be in standard position when its vertex is at the origin of a system of rectangular coordinates and its initial side extends in the positive direction along the x axis. Angle θ in the drawing of an angle in the first quadrant is in standard position.

In trigonometry, an angle is called a positive angle if it is generated by a line revolving counterclockwise. If the generating line revolves clockwise, the angle is called a negative angle. In the computer, positive angles are generated by rotating a potentiometer arm counterclockwise and negative angles by rotating it clockwise. The important point to remember is that if a certain direction of



ANGLE IN FIRST QUADRANT

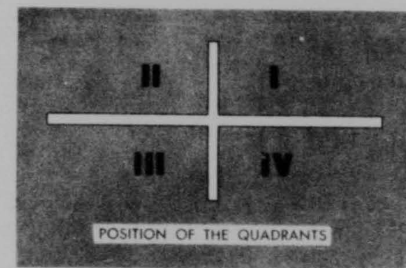
rotation generates positive angles, opposite rotation generates negative angles.

In the drawing, angle θ is generated by rotating vector OP from its original position, OX. If a perpendicular line is drawn from point P to the X axis, a right triangle is formed, and the function of angle θ can be given as follows:

$$\sin\theta = \frac{Y}{r} = \frac{\text{ordinate}}{\text{radius}}$$

$$\sin\theta = \frac{x}{r} = \frac{\text{abscissa}}{\text{radius}}$$

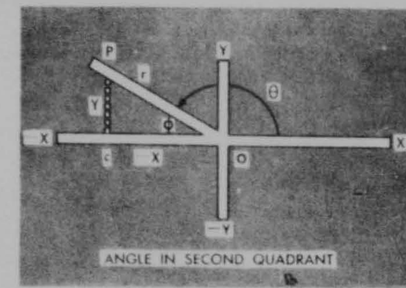
$$\tan\theta = \frac{Y}{x} = \frac{\text{ordinate}}{\text{abscissa}}$$



POSITION OF THE QUADRANTS

Beginning with the upper right quadrant (quarter of circle) and going on in a counterclockwise direction, the various quadrants are numbered as shown. Thus, positive angles from 0° to 90° are in the first quadrant, from 90° to 180° in the second quadrant, from 180° to 270° in the third quadrant, and from 270° to 360° in the fourth quadrant. Negative angles from 0° to 90° are in the fourth quadrant, from 90° to 180° in the third quadrant, and so on. Using the unit circle, the functions of angles in the various quadrants are obtained as follows:

The absolute value of the functions of angle θ in the second quadrant are obtained from the table by using the supplement of the angle (180° minus the angle). In the drawing, this is angle φ in the right triangle PCO. Consequently, the signs of the function can be obtained by using angle φ. In determining the signs, always consider r to be positive and determine the signs of the abscissa (x values) and the ordinates (y values) by the quadrants in which they are located.



ANGLE IN SECOND QUADRANT

$$\sin(180° - \theta) = \frac{Y}{r} = \sin\phi$$

$$\cos(180° - \theta) = \frac{-x}{r} = -\cos\phi$$

$$\tan(180° - \theta) = \frac{y}{-x} = -\tan\phi$$

Thus, in the second quadrant, the sine is positive while the cosine and tangent are negative.

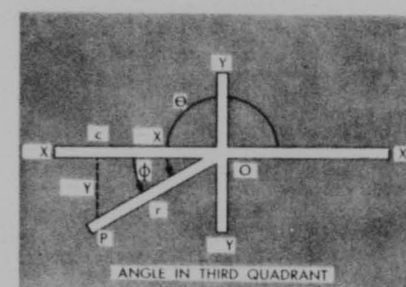
The absolute values of the functions of angle θ in the third quadrant are obtained from the tables by using the difference (angle φ) between angle θ and angle θ and 180°. Here, too, the signs of the functions are obtained by using angle φ in the right triangle PCO.

$$\sin(\theta - 180°) = \frac{-y}{r} = -\sin\phi$$

$$\cos(\theta - 180°) = \frac{-x}{r} = -\cos\phi$$

$$\tan(\theta - 180°) = \frac{-y}{-x} = \tan\phi$$

Thus, in the third quadrant, the sine and cosine are negative while the tangent is positive.



ANGLE IN THIRD QUADRANT

The absolute values of the functions of angle Θ in the fourth quadrant are obtained from the table by using the difference (angle ϕ) between 360° and angle Θ. The signs of the functions are again established by using angle ϕ in the right triangle PCO:

$$\sin(360 - \Theta) = \frac{-Y}{r} = -\sin\phi$$

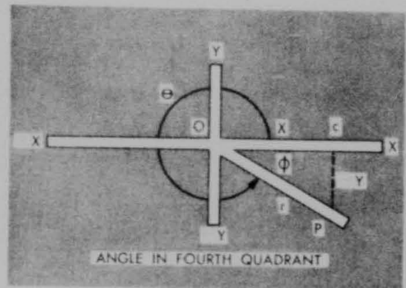
$$\cos(360 - \Theta) = \frac{x}{r} = \cos\phi$$

$$\tan(360 - \Theta) = \frac{-y}{x} = -\tan\phi$$

Thus, in the fourth quadrant, the sine and tangent are negative while the cosine is positive.

Summarizing, one can find the function, absolute value, and sign of any positive angle if one locates it in the proper quadrant according to its size and use the acute angle of the right triangle formed by a perpendicular from any point P on the rotating vector to the X axis. One must observe the sign of the x and y values in the various quadrants. The table summarizes the signs of the functions of positive angles.

FROM—To	SINE	COSINE	TANGENT
0°—90°	+	+	+
90°—180°	+	—	—
180°—270°	—	—	+
270°—360°	—	+	—



ANGLE IN FOURTH QUADRANT

In studying the computer of the **APQ-23**, one will deal also with negative angles. Remember that negative angles are caused by opposite rotation of the rotating vector. The functions of negative angles in the first quadrant are the same as those of positive angles in the fourth quadrant. Observe the signs of the x and y values.

$$\sin(-\Theta) = \frac{-y}{r} = -\sin\Theta$$

$$\cos(-\Theta) = \frac{x}{r} = \cos\Theta$$

$$\tan(-\Theta) = \frac{-y}{x} = -\tan\Theta$$

By comparing the signs of these functions with the signs of the functions of a positive angle in the first quadrant, one can see that the sign of the sine and tangent functions of negative angles is opposite to that of positive angles, while the sign of the cosine function is the same for both positive and negative angles. These relations are true for any value of $-\Theta$, regardless of the quadrant or magnitude of the angle. The table summarizes the signs of the functions of negative angles.

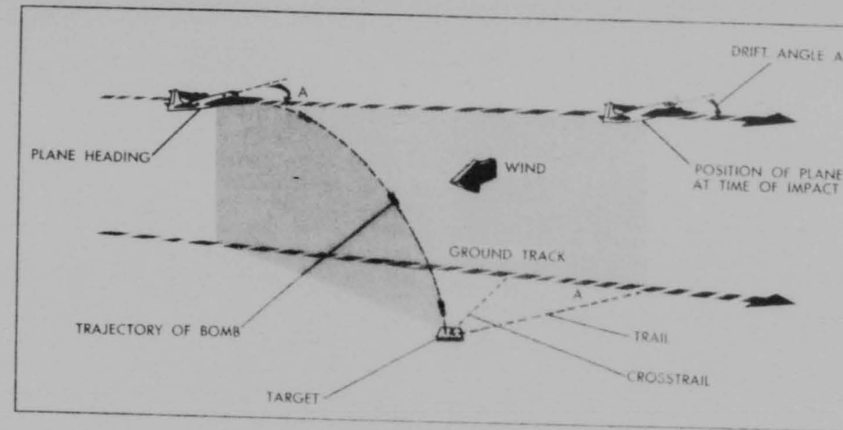
Negative Angles

FROM—To	SINE	COSINE	TANGENT
0°—90°	—	+	—
90°—180°	—	—	+
180°—270°	+	—	—
270°—360°	+	+	+

10. BASIC BOMBING GEOMETRY

The chief problem of bombing is to determine the exact point at which to release the bomb. Since the bomb has to cover both a horizontal and a vertical distance to reach the target, the problem resolves itself into a question of how long it takes the bomb to fall and the distance it covers in that time. The vertical distance is the altitude of the plane at release, and the time the bomb takes to cover it (the time of fall) is determined by gravity and the ballistics of the bomb. The horizontal distance traveled by the bomb in that time depends on the speed of the plane, the resistance of the air, the wind direction and speed, and the ballistics of the bomb.

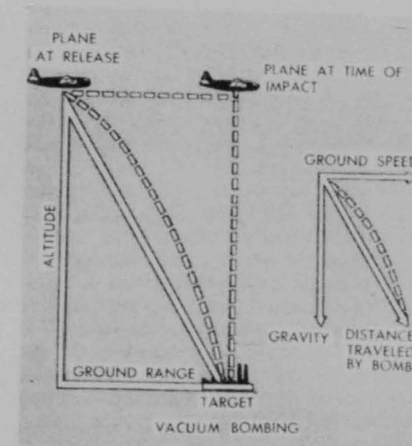
The simplest case of bombing would be one set up in a vacuum. In this set-up, only two factors would determine the distance traveled by the bomb—the altitude and the ground speed of the plane. At the moment of release, the bomb would be moving at the same speed as the plane, and since in a vacuum, there would be nothing to slow its speed, it would continue to travel at that speed as it fell. Consequently, it would be under the



Perspective View of Bombing Geometry.

plane at all times, and the plane would be directly over the target at the time the bomb hit. To figure out the release point of the bomb in this case, it would be necessary to consider only the altitude (to determine the time of fall) and the ground speed of the plane (to determine the horizontal speed of the bomb).

Since bombing isn't done in a vacuum, there are many other factors that affect the bombing problem besides altitude and ground speed. One considers the same problem as before but

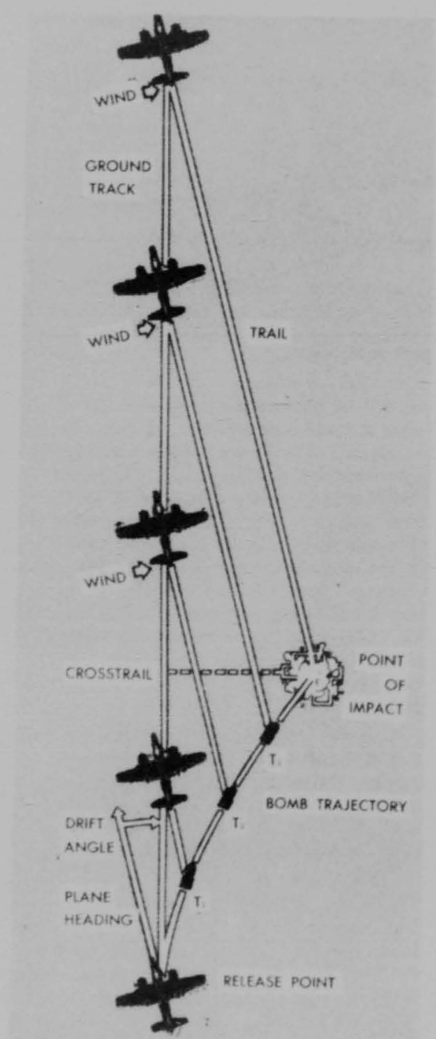


VACUUM BOMBING

in still air instead of a vacuum. Altitude and ground speed must still be considered, but the resistance of the air must also be taken into account. The air resistance continually reduces the forward velocity of the bomb so that it gradually lags farther behind the plane. The distance that the bomb lags behind the plane at the moment of impact is called trail. This distance depends on the altitude, the ground speed, and the type of bomb. In this case, the time of fall is still determined by altitude, but the distance covered by the bomb in that time depends on the type of bomb as well as the ground speed of the plane.

Now consider the same problem, not in still air, but with a headwind or a tail wind. One can readily see that the only difference is in the ground speed, and since the ground speed of the bomb and the plane are equally affected, the solution of the problem depends on the same things as in still air, namely the altitude, the ground speed, and the type of bomb.

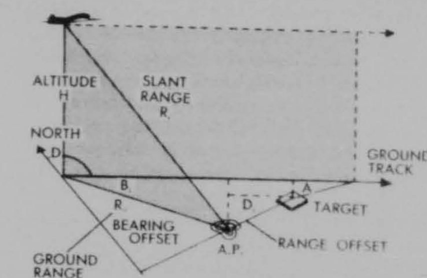
A crosswind presents a different problem. In a crosswind, the plane has to head into the wind to make good its ground track. The angle at which it heads into the wind, that is, the angle formed by the nose-to-tail line of the plane and the ground track, is called the drift angle. At release, the bomb is given a momentum along the ground track, but it does not make good the same track as the airplane



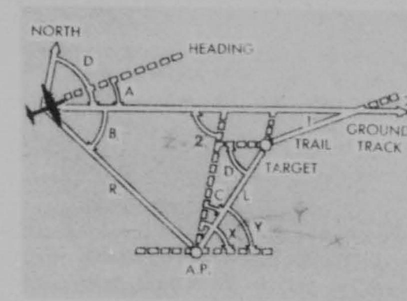
Horizontal Projection of Bombing Problem.

because its original momentum is gradually dissipated by the resistance of the air. Consequently, in a crosswind, the bomb only lags behind the plane, but it is also moved to the right or left of the ground track, depending on the direction of the wind. At the same time, because of the initial momentum given to it by the plane, the bomb lies underneath the extended nose-to-tail line of the plane, as shown in the illustration. Note that at each point, T-1, T-2, T-3, the bomb lies along the extended nose-to-tail line but lags behind and to the right of the plane. The distance it moves to the side is called crosstail. The size of this crosstail depends on the drift angle of the plane and the trail of the bomb. In this case, the time of fall is still determined by the altitude, but the distance covered by the bomb in that time depends on the drift angle as well as the type of bomb and the ground speed of the plane.

The bombing methods just discussed are called direct bombing because they involve aiming directly at the target. However, this is not always practical, for there are times when the target does not show up well on the radar scope. At such times offset bombing is used. In this method, some object that shows up well on the scope and is near the target is taken as the aiming point, and the calculations are based around that point instead of the target even though the bomb is still directed at the target. Offset bombing introduces new factors. Not only must the altitude, the ground speed of the plane, the drift angle, and the trail be considered, but the range offset (the distance between the aiming point and the target) and the bearing offset (the true bearing of the range offset line) must also be considered. These factors are shown in the offset bombing diagram. In the vertical triangle, that is the triangle formed by a line from the plane to the aiming point, a line from the plane to the ground directly below it, and a line from that point to the aiming point, the altitude is called H, the slant range, Rs, and the ground range, Ra. In the horizontal portion of the drawing, the drift angle is called angle A, the true bearing of the range offset line is called angle C, and the angle between the range offset line and the ground track is called angle Dc.



Offset Bombing.



Offset Bombing

Each of these terms is used by the computer in the solution of an offset bombing problem, as explained later. However, that explanation depends on the fact that angle Dc is equal to angle D minus angle C. This may well be proved here.

To make this proof, use the angle Dc and the drift angle diagram. Notice the two dashed lines constructed through the aiming point. One is parallel to the north-south line, and the other, parallel to the ground track, is called angle Dc.

	Reason
∠D = ∠Z = ∠Y	Alternate interior angles formed by a transversal cutting parallel lines are equal.
∠X = ∠Y − ∠C	By inspection.
∠X = ∠D − ∠C	Equals can be substituted for equals.
∠X = ∠Dc	Alternate interior angles formed by a transversal cutting parallel lines are equal.
∠Dc = ∠D − ∠C	Equals can be substituted for equals.

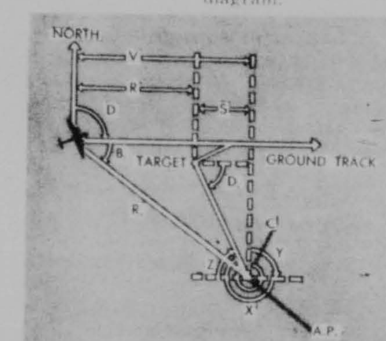
Another assumption made in the computer is that the drift angle A is equal to angle 2 in the diagram. That, too, can be proved here. Notice that the line from the target to the ground track (trail) is parallel to the heading line.

	Reason
∠A = ∠1	Alternate angles formed by a transversal cutting parallel lines are equal.
∠1 = ∠2	Vertical angles are equal.
∠A = ∠2	Things equal to the same things are equal to each other.

Sometimes, the diagram for an offset bombing problem is like the one shown below. In this case, angle Dc is still equal to angle D − c, although the signs of the trigonometric functions are not always the same for angle D − C as for angle Dc.

In the diagram, notice the two dashed lines constructed through the aiming point; one is parallel to the north-south line, and the other is parallel to the ground track. Also notice the dashed line constructed through the target parallel to the ground track.

	Reason
∠D = ∠Y	Same as in the previous proof for the previous diagram.



Offset Bombing

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$\angle Y - \angle C = -\angle X$	By inspection.
$-\angle X = \angle D - \angle C$	Equals can be substituted for equals.
$\angle X - 180° = \angle Z$	By inspection.
$\angle Dc = \angle Z$	Alternate interior angles formed by a transversal cutting parallel lines are equal.
$\angle Dc = \angle X - 180°$	Equals can be substituted for equals.

The trigonometric functions of angle Dc are the same as those of angle X.

To find the absolute value of the trigonometric functions of angles between 180° and 270°, the difference between the angle and 180 degrees is used.

Therefore, the absolute values of the functions of angle Dc are the same as those of angle X.

In this problem, you must establish the sign of the functions of D−C by dealing with the negative angle Dc. The sine function is positive and the cosine and tangent functions are negative, because the negative angle is between 180° and 270°. Remember this, as it will help you to understand certain applications of the bombing problems in the next chapter.

Another assumption made in the computer is that the distance R along the ground track is equal to Ra Cos Bc—L Cos Dc. This can be proved as follows:

	Reason
$R = V - S$	By inspection.
$CosBc = \frac{V}{Ra}$	Right triangle relationships.
$V = RaCosBc$	By multiplication.
$CosDc = \frac{S}{L}$	Right triangle relationships.
$L = S\,CosDc$	
$R = Ra\,Cos\,Bc - L\,Cos\,Dc$	Equals substituted for equals.

A thorough understanding of the problems discussed in this chapter will help to understand the development of the bombing equations in the following chapter. No attempt has been made to cover all the variations of the bombing problems. However, the principles discussed will apply to the geometry of any of the problems.

11. PROBLEMS SOLVED BY THE COMPUTER

The chief purpose of the computer is to determine the proper point at which to release the bombs in order to hit the desired target. To do this, the computer must solve a mathematical equation known as the "bomb-release equation." The computer can solve this equation properly if the proper information is set into it by the operator. This information consists partially of fixed factors, such as altitude, trail, and time of fall, and partially of variable factors, namely, ground range, ground speed, turn, and drift. By use of instruments and charts the operator can readily determine the fixed factors and set them in. However, he cannot accurately determine the variable factors without some check on his settings. For this reason, the computer solves two additional equations—the "variable range-circle equation" and the "steering equation"—which determine the position of reference lines on the scope and show the operator whether the continuously-variable information he set in was accurate, or, if not, how he must change it.

When the operator sets in altitude and ground range, the computer solves the variable range-circle equation, determines the slant range to the aiming point on the basis of the operator's settings, and puts a circle on the scope at this range. Since the position of the aiming point on the scope is an accurate indication of the slant range, the variable range circle should coincide with the aiming point. If it does, the operator knows that he has properly set the GROUND RANGE knob. If it does not, the operator can see that he must change the position of the GROUND RANGE knob until the variable range-circle coincides with the aiming point. The variable range circle also enables the operator to set the GROUND SPEED knob correctly, for if it

is at the correct setting, the variable range circle will move in at a rate proportional to the ground speed of the plane and will track the aiming point. If the variable range circle does not track the aiming point, the operator can adjust the GROUND SPEED knob until it does. In this way, the solution of the variable range-circle equation by the computer enables the operator to set accurate ground range and ground-speed information into the computer.

The solution of the steering equation by the computer positions a visual indicator—the azimuth marker—on the scope and enables the radar operator to determine whether the plane is being steered in the proper direction to permit the bombs to hit the target. This azimuth marker should always be on the aiming point. If it is not, the plane is off course, and the radar operator must adjust the TURN control to put the azimuth marker on the aiming point and the plane on course. (When control is at the pilot's position, adjustment of the TURN control does not actually change the plane's heading, for then the TURN control is not connected to the automatic pilot; it merely indicates to the pilot via the PILOT'S DIRECTION INDICATOR how he should change the heading). If the azimuth line is put on the aiming point, but does not stay on, it indicates that the plane is getting off course (presumably because of drift), and the radar operator can use the DRIFT control to correct the heading of the plane to compensate for drift and put the azimuth line back on the aiming point. In this way, the solution of the steering equation enables the radar operator to steer the plane properly, or, if the pilot is flying the plane, to give the proper corrections to the pilot on the PILOT'S DIRECTION INDICATOR.

Besides solving the variable range-circle equation, the steering equation, and the release equation, the computer also solves a fourth equation—the "sighting-angle equation." While the solution of this equation is not necessary for the actual bombing, it serves a valuable purpose in furnishing continuous information to the bombardier for synchronizing the optical bombsight with the radar so that he can make a visual assist if the opportunity occurs.

The exact nature of the four equations solved by the computer varies with the type of bombing problem encountered. To help understand these equations, they are developed in the following pages. The equations for the simplest case of bombing are considered first; then these equations are gradually broadened in logical sequence to cover more and more complicated situations, until a set of equations is developed to cover the most complicated problem, namely, offset bombing with drift. The final set of equations arrived at is applicable to all cases, and operation of the computer is based on these equations.

In the case of direct bombing without drift, the plane is flown directly over the target, the path of the bomb after release is the same as that of the plane, and there is no special problem of steering. Only the variable range-circle equation, the release equation, and the sighting-angle equation have to be solved.

Variable Range-circle Equation

The variable range-circle equation solves for the slant range on the basis of the altitude and ground range set in by the operator. It is obtained from the vertical triangle, the three sides of which are: altitude (H), slant range (Rs), and ground range (Ra). The equation is based on the relationship that exists between the base, altitude, and hypotenuse of a right triangle, namely, $(Altitude)^2 + (Base)^2 = (Hypotenuse)^2$. Substituting from the vertical triangle: $H^2 + Ra^2 = Rs^2$

Transposing: $H^2 + Ra^2 - Rs^2 = 0$

This is the variable range circle equation. Note that the terms of the equation have been transposed and made equal to zero. This is done with all equations in this chapter, for that is the exact form in which the computer uses the equations. A signal voltage proportional to each term in the equation is produced, summed up, and the result applied to the grid of an amplifier. If the equation is satisfied, the sum of the terms is zero, and no signal is applied to the amplifier. If the equation is not satisfied, a signal is applied to the amplifier, and the amplifier-circuit output causes a motor to rotate and balance the equation or, in some cases, a meter to indicate the results of the signal. In the case of the vari-

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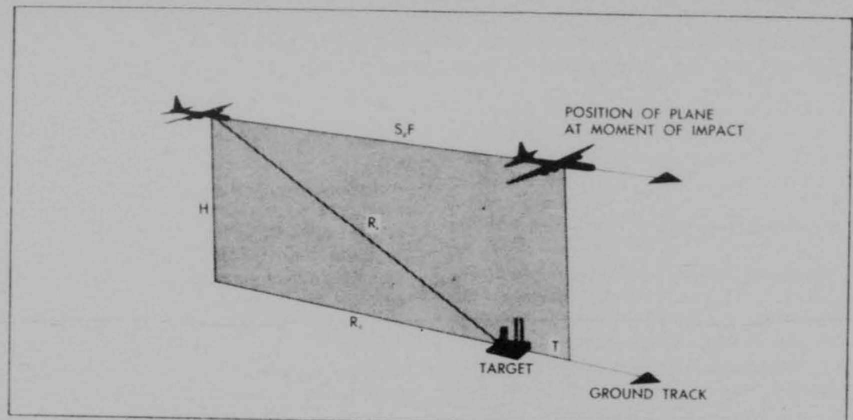


Direct Bombing without Drift.

able range circle equation, an unbalance is caused by a change in the ground range. The equation is balanced again by the automatic change in the Rs^2 signal. At the same time the variable range circle is repositioned. In the computer, two things cause a change in the ground range, a re-setting of the GROUND RANGE knob by the operator, and the progressive change in ground range by the rate motor. By continually checking the altitude, and by adjusting the GROUND RANGE and GROUND SPEED knobs to keep the variable range circle tracking the target, the operator can keep the ground range and slant range in the computer at an up-to-the-second accuracy.

Release Equation

If, after release, the bomb were to continue to travel at the same forward velocity as the plane, it would travel a ground distance equal to the ground range covered by the plane from the release point to the time of impact. Calling the ground speed of the plane Sg and the "time of fall" of the bomb F, the distance would be equal to SgF (the ground speed of the plane multiplied by the "time of fall"). However, because of air resistance, the bomb lags behind the plane a distance called trail (T), and the actual ground range from the plane at release to the target is SgF − T. That is also, by definition, the ground range Ra.

Therefore: $Ra = SgF - T$

Transposing: $Ra - SgF + T = 0$

Ra is the changing value of the equation. The result of the equation, that is, the difference between Ra and SgF − T is shown on the DISTANCE-TO-GO METER (distogometer). When Ra decreases to the point where the difference is equal to 0, the meter reads 0, and the bombs are released.

Sighting-angle Equation

In synchronous bombing, the problem is to compare the distance from the ground position of the plane to the target as determined by the APQ-23 to the distance as determined by the Norden bombsight. In the case of direct bombing without drift, the APQ-23 distance to the target is called RA, and the Norden distance to the target is called Rn. For the Norden to be synchronized with the APQ-23, the following equation must be satisfied:

$Ra = Rn$

Transposing: $Ra - Rn = 0$

This is the sighting-angle equation. The balance or unbalance of this equation is shown on the SA METER. If the Norden rate is properly synchronized with the APQ-23, Rn will change at the same rate as Ra, and the SA METER will indicate 0. If it does not change at the same rate, the bombardier has to change the rate of the Norden to bring the SA METER to 0 and keep it there.

By comparing the drawings for direct bombing without drift and with right drift, one will find that the vertical-triangle portion of the problem is the same for both. However, in the case of direct bombing with drift, because of crosstail, additional information is needed to establish the correct ground course. The pilot must know just how far the plane must be flown upward from the target. In this case, RA is still the ground range to the target, but it is not along the ground track. Also, angle Bc and angle A enter the picture. Angle Bc is the angle between the ground track and the line drawn through the target. Angle A is the drift angle, that is the angle between the nose-to-tail line of the plane and the ground track.

Variable Range-circle Equation

This equation is the same as in the previous case. $H^2 + Ra^2 + Rs^2 = 0$

Steering Equation

A course must be steered to compensate for drift and for the resulting crosstail. In the diagram, x (the crosstail) is common to both horizontal triangles. T (trail) is a fixed distance and is set into the computer from a prepared chart. Assume that the rate has been killed and that Ra is correctly set. Assume also that drift has been killed, and the proper course established. Angle A and angle Bc will then be correctly set in the computer. Then applying trigonometry: $x = Ra \sin Bc$ and $x = T \sin A$

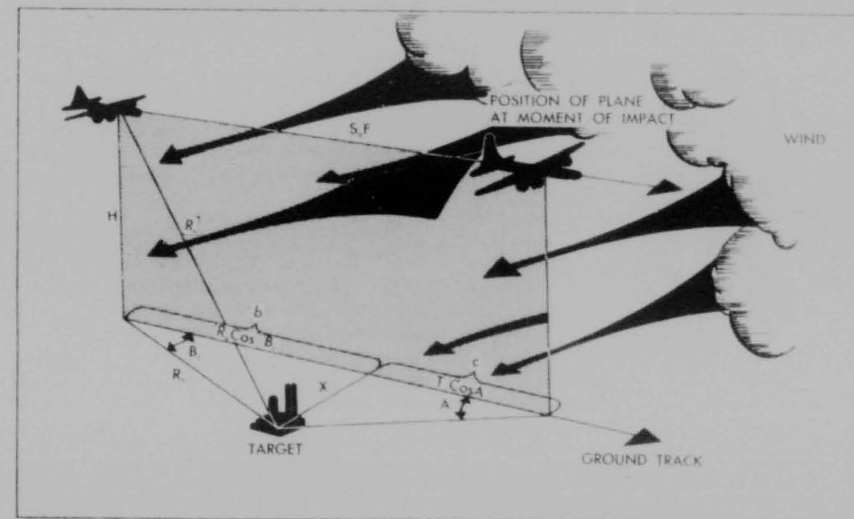
Therefore: $Ra \sin Bc = T \sin A$

Transposing: $Ra \sin Bc - T \sin A = 0$

This is the steering equation for the case of direct bombing with right drift. When the proper course is established, this equation will balance and the target will move down the azimuth marker. If the plane is not steered along the correct course, the equation will be unbalanced, and the azimuth marker will be off the target. It will then be possible to place the azimuth marker through the target by adjusting turn and drift to the point where the azimuth marker and the target coincide. It is possible also to overcompensate the turn and drift and momentarily make the target and marker coincide, but this will not establish the correct course, and the target will continually move away from the marker.

Release Equation

In the problem of direct bombing with no



Direct Bombing with Right Drift.

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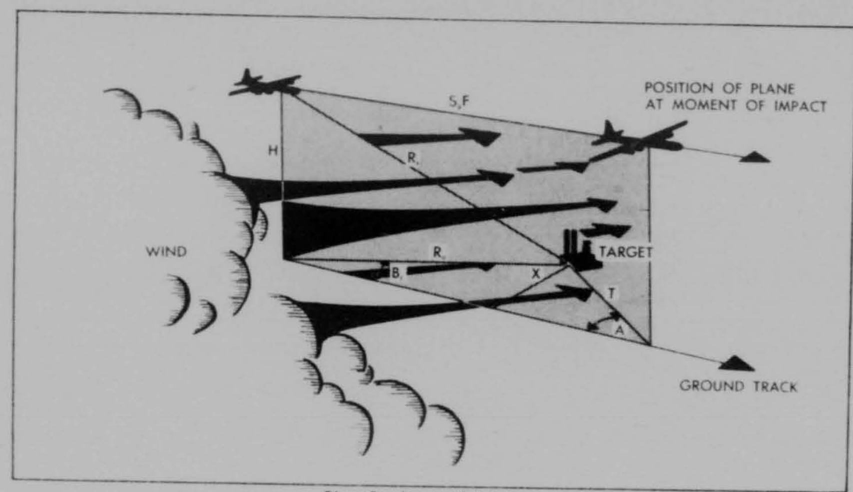


Direct Bombing with Left Drift.

drift the release equation was established as follows: Ra − SgF + T = 0. Where there is drift, Ra no longer lies along the ground track, and is not used directly in the release equation. Instead, the distance along the ground track must be used.

As can be seen from the diagram in direct bombing with right drift, SgF is equal to b + c. By trigonometry, one can see that b equals Ra Cos Bc and c = T Cos A. In other words:

Ra Cos Bc + T Cos A = SgF

Transposing:

Ra Cos Bc − SgF + T Cos A = 0

In the actual release equation, T (trail) is substituted for T Cos A. The error caused by the difference in the length of the hypotenuse (T) and the base of the right angles (T Cos A) is very minor. This error, referred to as the "range component of crosstail error", is ignored in the release equation. Therefore the release equation for direct bombing with right drift is: Ra Cos Bc − SgF + T = 0

Ra and Bc are the changing values in this equation, and the computer continually solves for the value Ra Cos Bc, and indicates the difference between Ra Cos Bc and SgF − T on the distogometer. When this difference reaches 0, the bombs are released.

Sighting-angle Equation

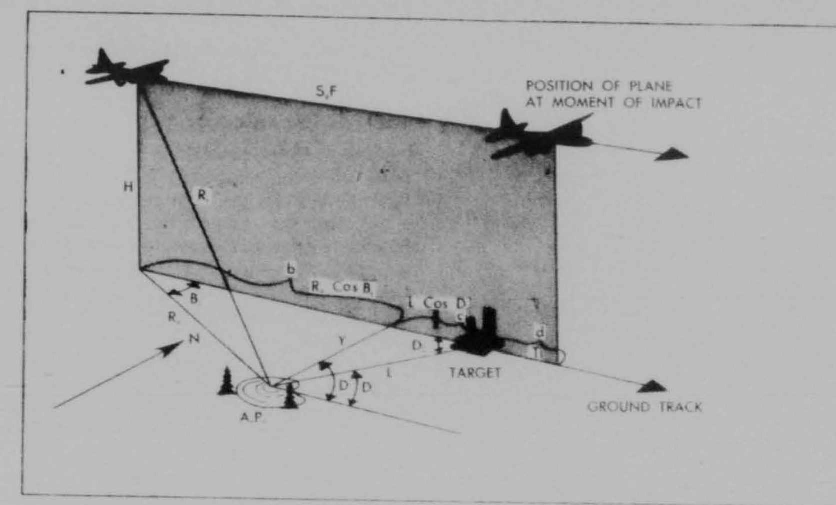
The problem that exists here is similar to the previous case of direct bombing without drift. In that case, the APQ-23 ground range (Ra) to the target was compared with the ground range of the Norden (Rn). However, in this as well as in all following cases in this chapter, the APG-23 distance that is compared with the ground range of the Norden bombsight is not the ground range to the target itself but to a point on the ground track that is opposite the target. The APQ-23 distance now becomes Ra Cos Bc. Therefore, Ra Cos Bc = Rn.

Transposing, the Sighting Angle Equation becomes: Ra Cos Bc − Rn = 0.

In comparing the left- and right-drift drawings, one can readily see that the terms in each are identical, but that some change must be made in the steering equation because the plane is flown on opposite sides of the target in the two cases.

Variable Range-circle Equation

The vertical triangle remains the same, and the equation is still $H^2 + Ra^2 - Rs^2 = 0$



Offset Bombing without Drift, Aiming Point before Target

Steering Equation

As in the steering equation for direct bombing with drift, two adjacent horizontal right triangles exist. The side y is common to both. Assuming that the proper course has been established, angle Bc, angle Dc, L, and Ra are all accurately set into the computer. Under these circumstances, the following equations are true:

Y = Ra Sin Bc and y = L Sin Dc

Combining these: Ra Sin Bc = L Sin Dc

Transposing: Ra Sin Bc − L Sin Dc = 0

This is the steering equation for offset bombing without drift, aiming point before the target. If this equation is satisfied, the azimuth marker extends through the aiming point during the entire approach of the plane. However, since in this case without drift, the equation is based on the proper setting of the TURN control, the equation is not satisfied until the control is properly set. For this reason, if the azimuth marker does not extend through the aiming point, the TURN control must be adjusted by the operator until the aiming point tracks down the azimuth marker.

Release Equation

As in the previous bomb release situation, the distance along the ground track of the airplane is the important consideration. Note from the diagram that, in this case, this distance is made up of three segments, b, c, and d. From the diagram one can also see that b is equal to Ra Cos Bc, c is equal to L Cos Dc, and d is equal to T. One can see, too, that the sum of these segments is equal to SgF, the total distance traveled by the bomb from the moment of release to the time of impact. In the form of an equation, this is:

Ra Cos Bc + L Cos Dc − SgF + T = 0

The distance Ra Cos Bc is continually decreased as the airplane approaches along the ground track. Consequently, the sum of the three terms Ra Cos Bc, L Cos Dc and T is continually decreasing. The difference between the sum of these terms and SgF is shown on the DISTANCE-TO-GO METER, and when it reaches 0, the bombs are automatically released.

Sighting-angle Equation

The APQ-23 ground range, as can be seen

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from the diagram, is Ra Cos Bc + L Cos Dc. To keep the Norden bombsight synchronized with the APQ-23, the ground range of the Norden (Rn) must be equal to this ground range. The sighting angle equation is therefore:

$Ra \text{ Cos } Bc - L \text{ Cos } Dc = Rn$

Transposing:

$Ra \text{ Cos } Bc + L \text{ Cos } Dc - Rn = 0$

As long as this equation is satisfied, the Norden bombsight is synchronized with the radar.

Changing the offset-bombing problem from aiming point before target to aiming point after target changes the ground-track distances and therefore changes the release and sighting angle equations. This does not affect the variable range circle equation or the steering equation.

Variable Range-circle Equation

The variable range circle equation is, as before: $H^2 + Ra^2 - Rs^2 = 0$

Steering Equation

The steering equation is, as in the case of offset bombing without drift, aiming point before target: $Ra \text{ Sin } Bc - L \text{ Sin } Dc = 0$

Note the angles around the aiming point. Angle Dc is still equal to the angle D—C but it is in the opposite quadrant than it was in the previous case. However, since the sine of a negative angle is the same in the third quadrant as in the fourth, the steering equation is unchanged.

Release Equation

As before, the problem is to find the distance along the ground track that is equal to SgF. As one can see from the drawing, b — c + d along the ground track is equal to SgF. Since b is equal to Ra Cos Bc, c is equal to L Cos Dc, and d is equal to T, the following equation is true:

$Ra \text{ Cos } Bc - L \text{ Cos } Dc + T = SgF$

Transposing:

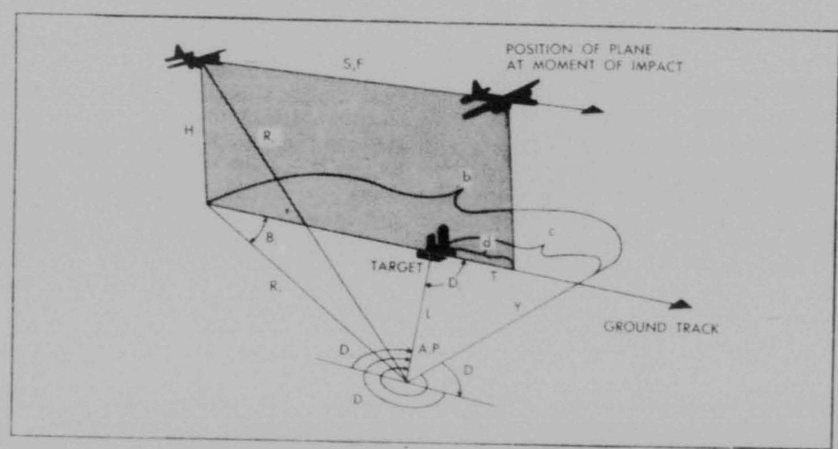
$Ra \text{ Cos } Bc - L \text{ Cos } Dc - SgF + T = 0$

This is the release equation for offset bombing without drift, target before aiming point. The only change from the previous case is the sign of L Cos Dc, which is now minus. This is due to the fact that the Dc angle is in the third quadrant.

Sighting Angle Equation

From the drawing one can see that the APQ-23 ground range is equal to b — c, or Ra Cos Bc — L Cos Dc. For synchronization of the Norden with the radar, this must be equal to the Norden range, Rn.

$Ra \text{ Cos } Bc - L \text{ Cos } Bc = Rn$



Offset Bombing without Drift, Target before Aiming Point.

Transposing:

$Ra \text{ Cos } Bc - L \text{ Cos } Dc - Rn = 0$

This is the sighting-angle equation for offset bombing without drift, target before aiming point. As in the release equation, the only change from the sighting-angle equation for offset bombing without drift, target after aiming point, is in the sign of L Cos Dc from plus to minus.

In offset bombing without drift, the ground track of the plane was far enough to one side of the aiming point to enable the plane to pass over the target. This is the distance y in the diagram. In case of offset bombing with right drift, the ground track of the plane must be flown and additional distance to the left of the aiming point to compensate for crosstail. This is the distance z; thus the total distance between the ground track and the aiming point is equal to y + z. This affects the steering equation. The distance along the ground track is very similar to that previously discussed in cases of offset bombing.

Variable Range-circle Equation

Again the variable range circle equation is $H^2 + Ra^2 - Rs^2 = 0$

Steering Equation

The distance between the aiming point and the ground track (x) is equal to y + z, as one can see from the diagram. One can also see that z = Ra Sin Bc, y = L Sin Dc, and z = T Sin A. Therefore, substituting in the equation x = y + z, it becomes Ra Sin Bc = L Sin Dc + T Sin A. Transposing: $Ra \text{ Sin } Bc - L \text{ Sin } Dc - T \text{ Sin } A = 0$

When this equation is satisfied, the azimuth marker extends through the aiming point. As before, the distance Ra is correctly checked by the variable range-circle. The satisfying of this equation depends on the angle Dc which in turn depends on the correct setting of the TURN and DRIFT controls.

Release Equation

Comparing the drawing of this problem to the drawing for offset bombing with no drift, aiming point before target, as for offset bombing without drift, aiming point before target. This equation is:

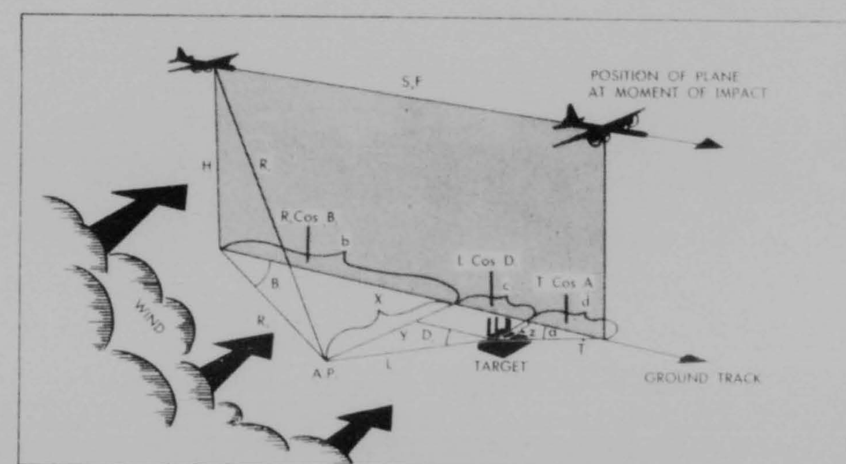
$Ra \text{ Cos } Bc + L \text{ Cos } Dc - SgF + T = 0$

Sighting-angle Equation

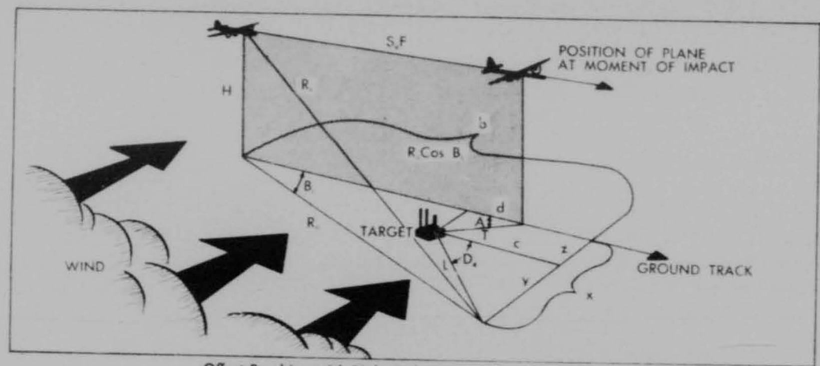
The sighting-angle equation is the same as for offset bombing without drift, aiming point before target. This equation is:

$Ra \text{ Cos } Bc + L \text{ Cos } Dc - Rn = 0$

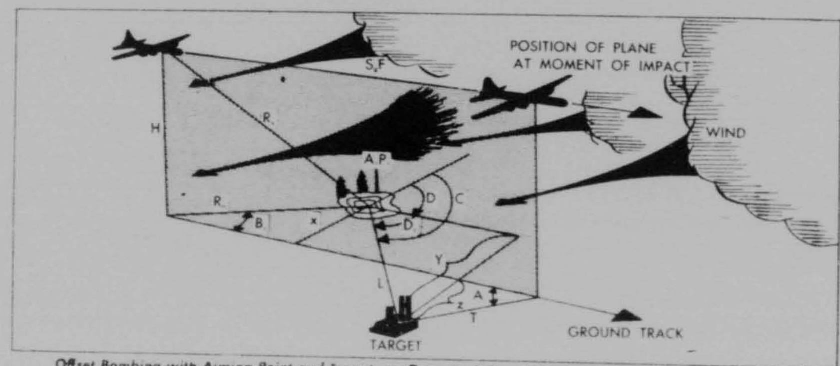
As usual, the Variable Range Circle Equation is the same as in all previous cases. If



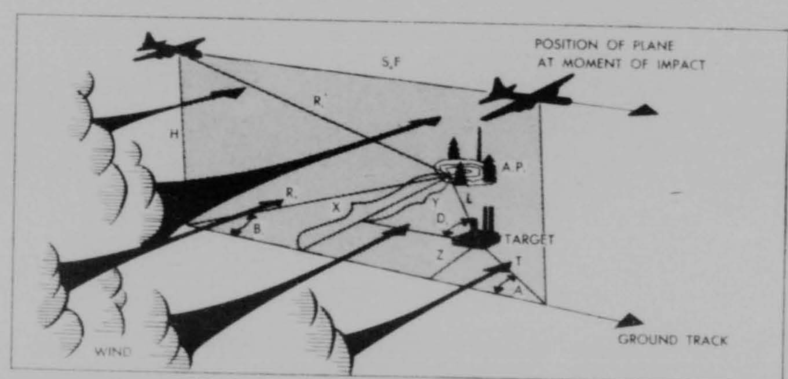
Offset Bombing with Right Drift, Aiming Point before Target.



Offset Bombing with Right Drift, Target Before Aiming Point.



Offset Bombing with Aiming Point and Target on Opposite Sides of Ground Track and with Right Drift.



Offset Bombing with Left Drift, Aiming Point before Target.

one develops the steering equation in the same way as it was developed in the case of offset bombing with right drift, aiming point before target, one will see that the steering equation here is the same as for that case. (Ra Sin Bc — L Sin Dc — T Sin A = 0.) Developing the release equation and the sighting-angle equation as in the case of offset bombing without drift, target before aiming point, one finds that these equations are the same here as in that case.

Release Equation:

Ra Cos Bc — L Cos Dc — SgF + T = 0

Sighting Angle Equation:

Ra Cos Bc — L Cos Dc — Rn = 0

The drawing for this case will strike one at first as being entirely different from those for the previous cases. However, if one derives the equations as was done in the previous cases, one finds that the variable range circle equation, release equation, and the sighting-angle equation are identical to those for offset bombing with right drift, aiming point before target. The steering equation, however, is different.

Steering Equation

One can develop the steering equation here as before. Since the aiming point and the target are on opposite sides of the ground track, one can see that the basic equation changes from x = y + z, which was used in the previous case, to y — z = x. As before x = Ra Sin Bc, y = L Sin Dc, and z = T Sin A. Substituting these terms in the equation y — z = x, one has:

L Sin Dc — T Sin A = Ra Sin Bc

Transposing:

If one develops the variable range circle, the release, and the sighting-angle equation, one will see that these three equations are the same as in the case of offset bombing with right drift, aiming point before target. Only the Steering Equation is revised.

Steering Equation

One can develop the steering equation as in the previous examples. By inspection one can see that y + z = x and that x = Ra Sin Bc, y = L Sin Dc, and z = T Sin A.

Substituting:

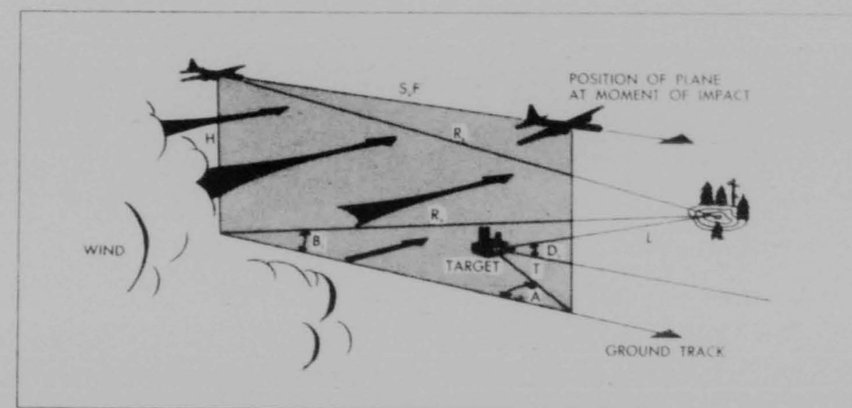
L Sin Dc + T Sin A = Ra Sin Bc

Transposing:

— Ra Sin Bc + L Sin Dc + T Sin A = 0

Developing the equations for this case, one can see that the variable range circle-equation is the same as in all previous cases, the steering equation is the same as for offset bombing with left drift, aiming point before target

(— Ra Sin Bc — L Sin Dc — T Sin A = 0), the release equation is the same as for offset bombing with right drift, target before aiming point



Offset Bombing with Left Drift, Target before Aiming Point.

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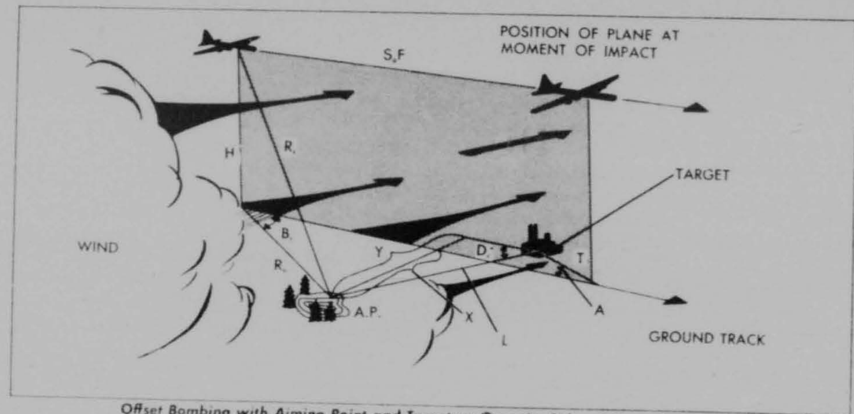


Offset Bombing with Aiming Point and Target on Opposite Sides of Ground Track and with Left Drift.

(Ra Cos Bc + L Cos Dc — SgF + T = 0), and the sighting-angle equation is the same as for offset bombing with right drift, target before aiming point (Ra Cos Bc − L Cos Dc − Rn = 0).

Except for the steering equation, the equations are the same as for the same problem with right drift.

Steering Equation

By examining the drawing one sees that the factors on the steering equation are the same as for the same problem with right drift except that they are on opposite sides of the ground track. In this case, therefore, the equation is x − y = z. Again, x = Ra Sin Bc, y = L Sin Bc, and y = L Sin Dc, and y = T Sin A

Substituting:

Ra Sin Bc − L Sin Dc = T Sin A

Transposing:

Ra Sin Bc − L Sin Dc − T Sin A = 0

Summary

Only a few of the many different bombing possibilities have been discussed in this chapter. However, by examining the table of the equations that have been developed, it is readily seen that the same pattern exists throughout.

One finds, for example, that the same terms are used in the equations for all cases where they apply. Thus, Ra Sin Bc, L Sin Dc, and T Sin A are the terms in the steering equation in all cases except direct bombing and offset bombing without drift. In the case of direct bombing, L Sin Dc does not apply, for there is no offset and the term is 0. In the case of offset bombing without drift, T Sin A does not apply, for the drift angle is 0 and T Sin A is 0. In the release equation, the terms are Ra Cos Bc, L Cos Dc, SgF, and T in all cases except direct bombing where, again, L Cos Dc does not apply, for there is no offset, and L Cos Dc is 0. There is a pattern also for the signs of the terms. Notice, for example, that T Sin A is positive in the steering equation whenever there is left drift and negative in the steering equation whenever there is right drift. Similarly, L Cos Dc is positive in the release and sighting-angle equations when the aiming point is before the target and negative in these equations when the target is before the aiming point.

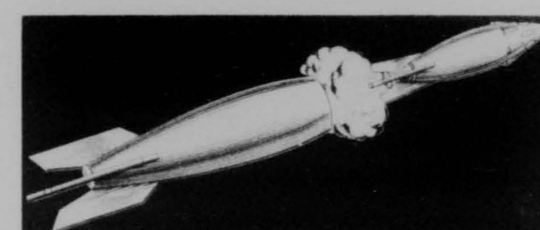
Because of this consistent pattern for all cases, the one set of controls on the computer can be used to set in all problems, and the mechanism can automatically arrive at the desired results. Take, for example, a case of direct bombing without drift. The release equation for this situation (Ra − SgF + T = 0) differs from the release equation for other situations in that it shows Ra instead of Ra Cos Bc and does not show L Cos Dc at all. The computer automatically takes care of the situations as follows: Since the drift angle

Condition	Variable Range Circle Equation	Steering Equation	Bomb Release Equation	Sighting Angle Equation
Direct bombing without drift	H² + Ra² − Rs² = 0	None	Ra − SgF + T = 0	Ra − Rn = 0
Direct bombing with right drift	H² + Ra² − Rs² = 0	Ra Sin Bc − T Sin A = 0	Ra Cos Bc − SgF + T = 0	Ra Cos Bc − Rn = 0
Direct bombing with left drift	H² + Ra² − Rs² = 0	−Ra Sin Bc + T Sin A = 0	Ra Cos Bc − SgF + T = 0	Ra Cos Bc − Rn = 0
Offset bombing without drift, A. P. before target	H² + Ra² − Rs² = 0	Ra Sin Bc − L Sin Dc = 0	Ra Cos Bc + L Cos Dc − SgF + T = 0	Ra Cos Bc + L Cos Dc − Rn = 0
Offset bombing without drift, target before A. P.	H² + Ra² − Rs² = 0	Ra Sin Bc − L Sin Dc = 0	Ra Cos Bc − L Cos Dc − SgF + T = 0	Ra Cos Bc − L Cos Dc − Rn = 0
Offset bombing with right drift, A. P. before target	H² + Ra² − Rs² = 0	Ra Sin Bc − L Sin Dc − T Sin A = 0	Ra Cos Bc + L Cos Dc − SgF + T = 0	Ra Cos Bc + L Cos Dc − Rn = 0
Offset bombing with right drift, target before A. P.	H² + Ra² − Rs² = 0	Ra Sin Bc − L Sin Dc − T Sin A = 0	Ra Cos Bc − L Cos Dc − SgF + T = 0	Ra Cos Bc − L Cos Dc − Rn = 0
Offset bombing with right drift, A. P. before target on opposite sides of ground track	H² + Ra² − Rs² = 0	Ra Sin Bc + L Sin Dc − T Sin A = 0	Ra Cos Bc + L Cos Dc − SgF + T = 0	Ra Cos Bc + L Cos Dc − Rn = 0
Offset bombing with left drift, A. P. before target	H² + Ra² − Rs² = 0	−Ra Sin Bc + L Sin Dc + T Sin A = 0	Ra Cos Bc + L Cos Dc − SgF + T = 0	Ra Cos Bc + L Cos Dc − Rn = 0
Offset bombing with left drift, target before A. P.	H² + Ra² − Rs² = 0	Ra Sin Bc + L Sin Dc + T Sin A = 0	Ra Cos Bc − L Cos Dc − SgF + T = 0	Ra Cos Bc − L Cos Dc − Rn = 0
Offset bombing with left drift, A. P. before target on opposite side of ground track	H² + Ra² − Rs² = 0	Ra Sin Bc − L Sin Dc + T Sin A = 0	Ra Cos Bc + L Cos Dc − SgF + T = 0	Ra Cos Bc + L Cos Dc − Rn = 0

Bombing Equations

set in by the operator for this case is 0 and the Cos for an angle of 0° is 1, Cos Bc is 1, and Ra Cos Bc is exactly the same as Ra. Since the range offset put in by the operator is 0, L is 0, the term L Cos Dc is 0, and that term drops out of the computation. In this way, the computer automatically eliminates terms that do not apply.

The computer provides for a change in the signs of terms through the setting of the dials. Where the drift and bearing offset angles are such that the terms should be minus in the equation, the mechanism is so designed that, when the controls are set at those angles, a minus voltage is derived from the potentiometer. Where the angles are such that the terms should be plus in the equations, the mechanism is so designed that, when the controls are set for such angles, the potentiometer gives a plus voltage. The precise manner in which this is accomplished within the computer is explained in the following chapters.



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ConAC Manual 50-1[illegible]
April 19[illegible]

AIR FORCE COMMUNICATIONS
VOLUME II

AIR FORCE ROTC

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CONTINENTAL AIR COMMAND

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Foreword

HEADQUARTERS
CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK
25 April 1949

ConAC Manual 50-12 Vol. II is published for the information and guidance of all concerned. It will be used in conjunction with the current program of instruction pertaining to Air Force ROTC Training.

BY COMMAND OF LIEUTENANT GENERAL WHITEHEAD

HEADQUARTERS OFFICIAL CONTINENTAL AIR COMMAND

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Vice Commander

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Colonel, United States Air Force
Adjutant General

THIS MANUAL SUPERSEDES ConAC Manual 50-100-1, 50-200-2 Vol. II, Part 9.

Preface

THIS textbook has been prepared specifically for the college or university student who is participating in the Air Force ROTC program. It is one volume of a series designed to qualify him as an officer specialist in the United States Air Force.

The text is planned to indoctrinate the officer candidate in the fundamental principles of Air Force Communications, rather than to present a detailed treatise of the entire complex field.

In order to achieve maximum efficiency and effectiveness in the performance of his duties, the Air Force officer must be constantly aware of new developments in his specialty and its allied fields. A receptive mind, nurtured by supplementary research and reading, can be a vital force in the personal and professional development of the officer specialist throughout his career.

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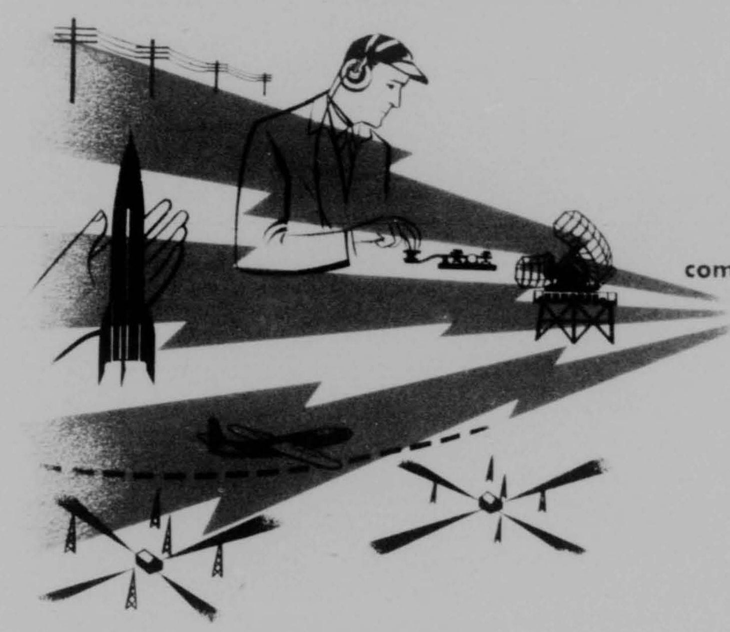
CHAPTER 1 - INTRODUCTION



communications and electronics

SECTION 1 - BACKGROUND

Effective control over the composite elements of a military force is imperative to successful military action. This control depends almost entirely upon the ability of the commander to make his will known to his subordinates, which, in turn, obviously involves some sort of communications. When military operations were relatively primitive, the commander shouted his orders. At a later period as armies grew in size and operations became more involved, the commander's voice was wholly inadequate, and his decisions were made known by prearranged signals, such as the sound of a bugle, the roll of a drum, or the firing of a flare. These simple communications served fairly well when the field was limited, but they too became hopelessly obsolete as battles and battle areas grew in magnitude.

As late as the American Civil War the orders of commanding generals were conveyed to subordinate commanders by mounted couriers. This system of combat communications, while colorful, was at best highly vulnerable. Often, and at critical times, the courier failed to reach his destination and failure to do so often resulted in defeat.

Warfare in the twentieth century is bewildering in its complexity. Advances in technology have produced weapons which compel total mobilization of the nation's manpower, materiels, and productive capacity. Armies once composed of thousands are now composed of millions. Each soldier has become a trained specialist and numerous activities must be precisely coordinated in order to accomplish the over-all mission. This welding of many parts into an organic

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whole is achieved by means of unobstructed communications. Destroy these lines of communication and the efficient army becomes a chaotic mob. Open lines of communications provide the means for effective control; impaired or imperiled lines endanger control; disrupted or destroyed lines lead to military defeat.

Think of the United States Air Force as you would think of your body. Think of the numerous parts of the Air Force as you would think of the parts of your body. Hundreds of thousands of cells unite to form your little finger. You can move your little finger up and down and sideways, and you can coordinate it with other bodily actions by means of the will of your brain. Your will is transmitted by your body's lines of communication (your nervous system) to the cells composing your finger. This illustration is analogous to military operations. One man in Washington, the brain or Chief of Staff, can direct global warfare and control the action of every man in his gigantic striking force by means of the military **nervous system**—the lines of communications.

During World War II, command from remote locations was the rule rather than the exception. The activities of the tactical air forces were closely coordinated with the movements of the allied armies. The units of the Twentieth Air Force were based in the Mariana Islands of the Pacific, while the operations of those units were the result of directives from their headquarters in Washington, D. C. In both of these types of operation, the need for centralized headquarters was imperative, and contact with the widely spread units was accomplished chiefly by radio.

In task force organization, hundreds of organizational units, each responsible for a separate and special assignment, were brought into concerted action as a great team and an irresistible task force by means of remote control was made possible by communications. General Eisenhower was able to command hundreds of ships and thousands of men on D-Day in Europe because of the channels of communications which reached every ship and every soldier participating in the invasion.

As the war progressed, this trend toward remote control and dependency upon communications became more marked. The Combined Chiefs of Staff and the Joint Chiefs of Staff, along with subordinate agencies, planned the grand strategy of the war in Washington and projected it by means of a world communciations network to the distant fighting fronts. This point is well illustrated in the case of the Twentieth Air Force.

Remote control is likely to become increasingly pronounced in the atomic and rocket age. The technological revolution in warfare is well under way. Weapons are reaching toward the ultimate in range, power, and speed. These developments are not to be dismissed as fantastic impossibilities, for they now exist as the grimmest of realities. Atomic bombs, approximating the absolute in destructive power; supersonic guided missiles; high speed submersibles equipped with rocket-firing facilities; these, along with other awe-inspiring innovations have heralded the pattern of future warfare. Should this country be forced into another conflict, the United States, by the new concept of war now evolving, will tend to become the main operating base, regardless of the disposition of the country's armed forces.

Discussion so far in this chapter has been limited to communications, which implies the

transference of intelligence from one human to another. This restricted concept is no longer in order. It is now improper to consider communications as a separate and distinct field from electronics. With the development of new weapons and new ideas of strategy, communications and electronics become more intimately related and interdependent. One must think of messages not only in the conventional manner, but also in terms of "impulses" sent out through space to provide remote control to a missile speeding toward a predetermined target at 2,000 miles per hour.

It becomes apparent that the field of communications and electronics must keep pace

and even anticipate other scientific advances. Failure in the field could and would result, in the final analysis, in general collapse of offensive and defensive action.

Never before has such a burden of responsibility rested upon the communications officer. In a very literal sense, the safety of the United States depends upon him. He must warn of the approach of a hostile force; he must guide the retaliating missile to its destination; he must keep the sea lanes free from hidden "schnorkels," and he must provide the means for the remote control of our armed forces all over the earth.

Proficiency in the field of communications and electronics requires considerable exacting application. There are compensations, however, for the officer with initiative and vision. He will soon realize that his opportunities for professional growth are very good and that he has an opportunity to make valuable contributions in this field.

SECTION 2 - DEFINITIONS

1. GENERAL

Communications and Electronics

The field of **communications and electronics** comprises all radio, wire, and other means for electrical transmission or reception of intelligence and all radar, radiation aids to aircraft and navigation, including control of guided missiles, radiation aids to fire control and bombing, radiation countermeasures and related radiation, and reradiation and all ancillary equipment. Specifically exempt from this field are nonradiating electrical devices, such as autopilots, fluxgate compasses, and kindred apparatus.

In a broad military sense, communications may be redefined as the means provided to extend the senses of the commander in terms of time and space. These means include all electrical, electronic, aural and visual media which, when assembled and integrated into an overall system, provide the required degree of operational and administrative control within the command.

Strictly speaking, this should be known as the **field of communications and electronics**; however, it has been abbreviated by general usage to **communications**.

Communication

Communication is the transmission of any messages except those sent by mail. The term message includes all oral, written, and pictorial communications, along with orders, reports, and instructions in plain language or encrypted.

Agency of Communications

Agency of communications embraces the personnel and equipment necessary to operate message centers, communication intelligence, communication supply, communication repair, and messenger, pigeon, radio, visual, sound, and wire communications.

Means of Communications

Means of communications indicates an agency of communications capable of transmitting messages. The following agencies are means of communication: messenger, pigeon, radio, semaphore, whistle, telephone, and telegraph.

2. AGENCIES OF COMMUNICATIONS

The following agencies of communication may be employed in the United States Air Force.

Message centers

Messenger communications, including:
- Air messenger
- Motor messenger
- Foot messenger (runner)

Radio communications, including:
- Radiotelegraph
- Radiotelephone
- Radioteletypewriter
- Radio facsimile

Wire communications, including:
- Telephone
- Telegraph
- Teletypewriter
- Facsimile

Visual communications, including:
- Lamps
- Flags
- Panels
- Pyrotechnics
- Smoke
- Hand and arms signals
- Maneuvers of aircraft

Sound communications

Radar installations, including:
- Ground radar installations
- Airborne radar installations

Electronic aids to navigation, including:
- Radio ranges
- Instrument landing devices
- Direction finding systems
- Loran
- Radio beacons
- Radio compass
- Radio altimeter
- Homing stations

Communications supply

Communications maintenance

DEPENDENT UPON SITUATION INVOLVED

3. MEANS OF COMMUNICATIONS

The communication systems within organizations of the United States Air Force generally employ one or more of the following means of communications: radio, wire, or messenger. Sound and visual communications are employed for special purposes. Choice of the means to be employed in every instance is dependent upon the situation involved as well as the suitability and availability of the means. In many instances, means are combined, i.e., radio links are used with wire communications. Exclusive reliance upon any one means is unwise since special and unforeseen circumstances may render that means inoperative or unsuitable when most needed. Plans of all commanders should make advance provision for the employment of as many different means as are regarded necessary to insure continuous communications and should include reliable alternate means. Simultaneous operation of several means minimizes the effect of complete interruption of any one. Generally, the principal means used for tactical purposes will be that which provides greatest facility and speed of installation and operation while insuring the necessary security and dependability.

Teamwork

To insure successful communication, the communications troops must work as a team regardless of unit, arm, or service. There must exist a spirit of mutual helpfulness and cooperation. The communications personnel at any headquarters should become acquainted with personnel at other headquarters with whom they communicate directly. This includes units in all relationships (supported, supporting, superior, subordinate, adjacent, and attached), and is true regardless of the point at which the responsibility for communication is fixed. Personal contact promotes a better understanding of the special problems and conditions which exist at each headquarters, and permits full assistance and cooperation in the installation, operation, and maintenance of communication. Coordination and cooperation are mandatory. This is especially true in joint operations with the Army, the Navy, and other air forces.

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SECTION 3 - COMMUNICATION DOCTRINE AND BASIC PRINCIPLES

1. GENERAL

In the design, construction, operation, and maintenance of communication systems, there are six basic principles upon which the systems must be founded. These are:

Principle of Reliability
Principle of Security
Principle of Speed
Principle of Economy
Principle of Flexibility
Principle of System Integration

Each of these principles must be carefully considered and assigned its proper weight. For example, in aircraft control communications speed may be of primary importance while security may be of only minor concern. On the other hand, certain command channels require the highest degree of security, while speed is secondary in importance. A full discussion of the application and balance of these factors is beyond the scope of this paragraph. Suffice to state that the balancing of these principles in the design and operation of a communication system is one of the most important decisions which can be made concerning the system.

2. PRINCIPLE OF RELIABILITY

Communications are vital to the proper control of military operations, and, to perform their proper role, must be available in its various forms when required by the commander.

Application of the principle of reliability of communications may consist of:

Engineering and building reliability factors into communications equipment. This includes specifying military characteristics so that the equipment will be sufficiently rugged to withstand the abuse of weather, transportation, and diversified operating conditions.

Engineering and building reliability factors into communications systems. This means the planning of alternate routes for communications channels to follow and the provision of alternate means of communications. In the latter, systems must be designed so that there will always be a standby means for handling traffic. For example, there must be radio channels to replace telephone channels, and there must be a courier, or messenger service to relieve some of the load placed on the electrical means. Additionally, this principle requires that the equipment selected be capable of handling the volume of message traffic which is anticipated and that it require a minimum of maintenance. Such other matters as the allocation of proper radio frequencies to the various nets so as to obtain maximum efficiency must be included in the planning of reliable communications.

Establishing adequate personnel programs and projects, including training programs and schedules, which produce personnel, as individuals or units, who are trained to meet unusual as well as routine problems. The morale of communications personnel has a major effect on the reliability of communications. In order to build and maintain this morale, there must be stated policies concerning training, assignment, and promotion. The individual is entitled to know the basis on which he will be promoted, that he will be assigned to the work for which he is best suited, and that he may expect to advance in his specialty.

Establishing adequate supply and maintenance programs and projects, including those for the welfare of personnel. A thorough maintenance program, especially preventive maintenance, is a major factor in insuring reliability of communications.

3. PRINCIPLE OF SECURITY

Proper application of this principle insures that the enemy is denied useful military information which he might otherwise obtain from friendly military communications. Security is of varying degrees. The design and operation of a communications system should provide the necessary degree of security consistent with the necessity for speed, reliability, and other military considerations.

Application of the principle of security to military communications consists of strict compliance with the provisions of AFR 205-1 **Safeguarding Military Information,** and strict application of principles and procedures as established in other appropriate documents.

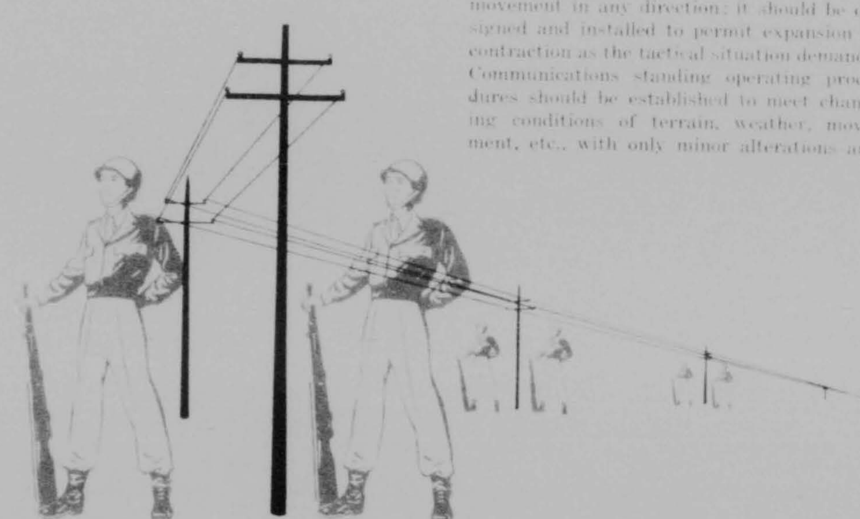
4. PRINCIPLE OF SPEED

The principle of speed of communications requires that systems be designed and operated so that information may be transmitted quickly enough to be useful in modern, high-speed warfare. While the need for speed has its greatest manifestation among the combat elements, the effect is felt even in the rearmost support elements; the requirement for speed in communications is present throughout the military establishment. The application of the principle of speed must be consistent with the necessity for security, reliability, and other military considerations.

Application of the principle of speed of communications may consist of:

Installation of direct, private, telephone, and teletypewriter facilities.

Application of privacy equipment to eliminate the necessity for a separate cryptographic process.



Use of carrier equipment to increase telecommunication channel availability.

Use of radio links in telecommunications to speed installation of networks.

Use of voice radio for such purposes as control of aircraft.

High standards of such personnel factors as operator training and morale.

5. PRINCIPLE OF ECONOMY

The principle of economy, as applied to communications, requires that the scale of communications be not more than that required to accomplish the mission successfully. This principle is an extension of one of the basic principles of warfare, **economy of force.** The application of this principle should be consistent with the necessity for reliability, security, flexibility, speed, and other military considerations.

6. PRINCIPLE OF FLEXIBILITY

The principle of flexibility of communications requires that communications systems be able to meet changing and diversified situations with only minor adjustments to the systems. Thus, a system should be designed and installed so as to permit freedom of movement in any direction; it should be designed and installed to permit expansion or contraction as the tactical situation demands. Communications standing operating procedures should be established to meet changing conditions of terrain, weather, movement, etc., with only minor alterations and

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modifications. Commanders must be free to act as the tactical situation demands without restrictions imposed by an inflexible communications system.

7. PRINCIPLE OF SYSTEM INTEGRATION

At first glance, it may seem that system integration should be a subdivision of other principles, such as flexibility, economy, and reliability. Such a surmise is partially correct, yet this principle is of such vital importance as to warrant separate consideration.

System integration includes: the blending of the separate communications nets, or systems, of subordinate units into the over-all communications system of the superior unit to produce one integrated system, and the adoption of common procedures throughout the integrated system.

SECTION 4 - THE USAF COMMUNICATIONS OFFICER

1. GENERAL

Normally, tactical unit commanders (and many service unit commanders) down to squadron level, are provided with a special staff officer trained in the tactics and techniques of communications. This office is charged, under the direction of the commander, with the exercise of tactical supervision of communications for the command. He is further charged with the duty of initiating, by means of proper recommendations, the necessary measures for the training of personnel and or subordinate units in communications for combat.

Channels of Supervision

Orders affecting the tactical employment of communications are issued through normal command channels (i.e., from the commander to a subordinate commander), and are coordinated with orders issued to other tactical or technical agencies by the appropriate staff section before issue. Orders pertaining to routine matters issued for the technical control of any agency of communications, and which need not be coordinated with orders issued to other elements of the command, may be issued (in the name of the commander) by the communications officer of the superior unit to the communications officer of a subordinate unit.

2. THE COMMUNICATIONS OFFICER (0200)

The following is a quotation from **AF Manual 35-1, Military Personnel Classification and Duty Assignment** (terminology used herein is that employed prior to National Defense Act of 1947):

Qualifications and Duties

Specification Serial Number (SSN) 0200

Directs or supervises the installation, operation, and maintenance of the signal communication agencies of a unit other than Signal Corps. Trains unit personnel in use of communication equipment; maintains efficient communication within a unit and with attached and supported units; establishes communications agencies as wire communications, radio communications, visual signaling, message centers, and messengers; supervises the enforcement of radio silence when in effect and provides for the use of runners and mounted messengers; supervises training of personnel in radio operation and maintenance; use of codes, construction, and maintenance of wire circuits, use of visual signals such as flags, flares and rockets, and message center operation and maintenance.

Must have thorough tactical and technical knowledge to insure establishment of necessary signal communication agencies according to tactical plans. Must be a specialist in Army signal communications systems.

Military experience essential and should include graduation from an officers' communication school.

Trade school or college training in electrical engineering desirable.

The above is a description of the duties of a communications officer (0200) plus the general qualities which must be present in an individual who would be one. From this, it must be obvious that the communications officer must be fully and carefully trained.

Staff Duties

As a member of the commander's staff, the communications officer is technical advisor to the commander and others on the staff on communications matters; he bears a staff responsibility for technical inspection of the communication systems of the command and subordinate units; he advises the commander and staff on matters of communications training and prepares the necessary training program under the general training policy as laid down by the commander and by higher authority; he takes steps to secure the required equipment throughout the command, and makes training inspections to insure proper progress in communications training.

SECTION 5 - NOMENCLATURE SYSTEM FOR COMMUNICATIONS EQUIPMENT

1. GENERAL

A supply system of so vast a scale as that required by the several parts of the national defense organization must have a system of item identification. Such a system must be both exact and brief. For supply purposes, the simple combination of stock number and nomenclature (one serving as a check on the other) fulfills both the requirements of exactness and brevity.

For other purposes (such as operations, planning, orders, and instruction), item identification is established by nomenclature alone. Therefore, nomenclature must be brief and specific. Each item, set, or group of equipment must be given a name which will serve to identify that particular article and nothing else. The "Dictionary of United States Army Terms" defines nomenclature as a "set or system of official names or titles given to items of material and equipment."

Communications and associated equipment of the Army, Navy, and Air Force is assigned its proper nomenclature under the Army-Navy Nomenclature System. This system was secured through joint agreement.

Prior to the adoption of this system in January, 1943, each service had its own system of nomenclature. The old system still exists since many of the items that were named in this manner are still in use. Therefore, it is well that the communications officer understand something about the use of both systems employed in the naming of the equipment.

2. ARMY-NAVY NOMENCLATURE SYSTEM

Development of AN System

The Army-Navy (AN) Nomenclature System was developed to establish a standard plan of naming communications and associated equipment of the two services in order to eliminate delays in interservice supply occurring when identical equipment of the Army and Navy differed in name. The same plan applies to the communications equipment used by the now autonomous Air Force.

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In developing the system, it was considered that it should:

Facilitate the operation of the Army and Navy supply services as well as speed inter-service supply.

Be logical in principle and easily understood.

Be flexible and broad enough in scope to cover all present types of equipment and new types to be developed in the future.

Avoid conflict with any then existing nomenclature systems.

Provide adequate identification on name plates without requiring the full name to be stated.

Provide a ready means of identifying equipments standardized for use by the Army and/or Navy and other United Nations.

Nomenclature Assignment Policy

The nomenclature system described pertains only to communications and associated equipment of the Army, Navy, and Air Force. The expression **associated equipment** extends the scope of the system to include many items essential to the proper operation or functioning of communications equipment such as power units, batteries, cases for equipment, and shelters or housing for equipment. Likewise, because of their long-standing associations with the Signal Corps, meteorological apparatus and photographic equipment receive AN nomenclature.

Communications equipment, which had been assigned nomenclature in the Signal Corps system prior to the adoption of the AN system in January, 1943, has not been redesignated. To avoid confusion, the AN System has been applied only to equipment developed since adoption of the system. Equipment formerly designated by Signal Corps nomenclature will continue to be so designed unless specifically changed by official order.

Army-Navy Nomenclature has been and will be assigned to: **complete sets of equipment** and **major components** of special design by or for the Army and Navy groups of items, of either commercial or military design, which are grouped for a special military communications purpose; **major units of equipment** of military design which are not part of or used with sets; and **commercial articles** when nomenclature will facilitate military identification and/or procedures.

A complete set is a complete group of equipment or major components, deriving power from outside or one or more included sources, which is capable of operating by itself and independently of other sets or accessories in performing its intended purpose. A major component is an item of a set which, when connected with associated equipment, will perform a major function.

Army-Navy Nomenclature is not assigned to:

Articles cataloged commercially except when nomenclature will facilitate military identification and/or procedures.

Minor components of special military design that can be identified in the stock number description by specification number, standard number, manufacturer's code number, or nomenclature of some other government agency.

Small parts such as condensers, resistors, etc., which continue to be identified by Army stock numbers or Navy type numbers.

Articles having other adequate identification in American War Standard or Joint Army-Navy Specifications.

The assignment of an AN Nomenclature is centrally controlled by the Joint Army-Navy Air Force Nomenclature Committee. Under no circumstances may other personnel or agencies originate or change any part of any AN Nomenclature assignment, including modification letters, unless the nomenclature previously has been approved and assigned by the aforementioned committee. Agencies performing authorized equipment modifications in the field may not add modification letters without authorization. Requests for new nomenclature assignments or changes are sent to the Joint Army-Navy Air Force Nomenclature Committee for action.

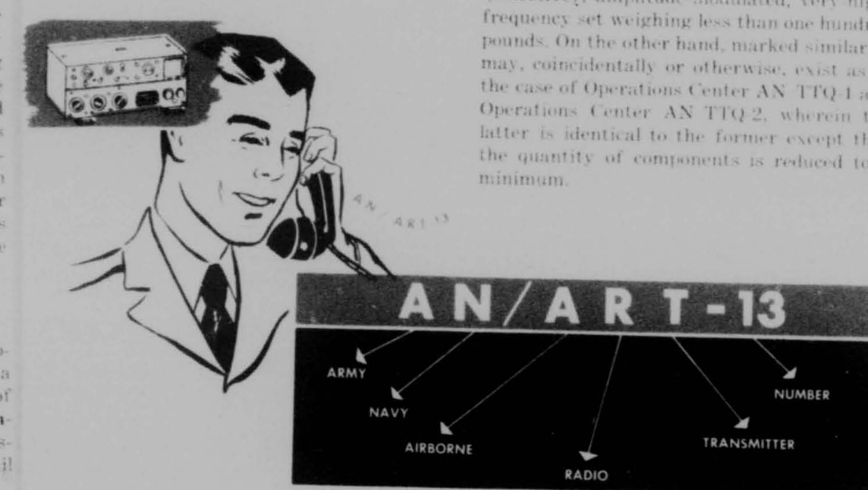
Composition of AN Nomenclature

In the AN system, (see Appendix) nomenclature consists of a name followed by a type number. The **name** is terminology of standard engineering usage. The **type number**, variable in composition, is characteristic of the system and is explained in detail

below. Some examples of complete nomenclature are as follows: Radio Set AN/ARC-3; Radio Transmitting Set AN/AR T-13; Telegraph Terminal TH-1/TCC-1; and Switchboard SB-5/PT. In the last example, switchboard is the **name;** SB-5/PT is the **type number.** Type numbers are composed as follows:

Type Numbers for Complete Sets. The type number for a complete set always contains the AN system indicator "AN" followed by a slant bar, indicator letter, and an assigned number. Example: AN/TRC-7. When applicable, modification letters and additional indicators are appended. The system indicator "AN", which is used only with type numbers for complete sets, does not mean that both the Army and Navy use the equipment but simply that the type number was assigned in the AN System and distinguishes it from similar type numbers in the Navy Model Letter System. The slant bar (/) serves only to separate the system indicator and the set or equipment indicator letters. The combination of indicator letters immediately following the slant bar is derived from, and interpreted by, the Table of Set or Equipment Indicator Letters in Appendix III. For complete sets, the type number always contains three of these indicator letters; the first letter indicating the type of installation, the second letter the general type of equipment, and the third letter the general purpose for which the set is used.

The number following the set or equipment indicator letters designates a specific complete set. It is an assigned number, a **model** number. Except in instances where suffix letters X, Y, and Z are applied as explained in Table I, or where letters are used to indicate functional interchangeability, different numbers are assigned to sets or equipment not electrically and mechanically interchangeable as a whole. As used in the type number AN/TRC-7, the number "7" indicates the seventh ground transportable radio communications set to which nomenclature has been assigned. The fact that two sets or equipments possess type numbers differing only in this assigned number, whether consecutive or not, does not imply any similarity of equipment other than that denoted by the set or equipment indicator letters. Thus, Radio Set AN/TRC-6 and Radio Set AN/TRC-7 are necessarily similar only in that each is a ground transportable radio communication set. No further similarity is implied. Radio Set AN/TRC-6 is an eight-channel (simultaneous), pulse-modulated, super-high frequency set weighing approximately five tons. Radio Set AN/TRC-7, however, is a two-channel (selective), amplitude modulated, very high-frequency set weighing less than one hundred pounds. On the other hand, marked similarity may, coincidentally or otherwise, exist as in the case of Operations Center AN/TTQ-1 and Operations Center AN/TTQ-2, wherein the latter is identical to the former except that the quantity of components is reduced to a minimum.



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When a set is modified for the first time, producing a minor variation in the functioning but not affecting interchangeability of the original and modified set of components, the basic nomenclature assignment is changed by the addition of the letter "A". Example: Radio Set AN ARC-7A indicates the first such modification of Radio Set AN ARC-7B, and so forth.

The use of modification letters, additional indicators for experimental sets and training sets, and the star (*) for United Nations Standardization is explained in Appendix III.

The reader should note that Appendix III presents an example of nomenclature for a complete set at the top of the table. Immediately under the example, the type number is expanded across the entire page. Under each letter or figure of the type number appears an explanation of that particular element of that type number. Additional examples of type numbers, with their meanings, appear at the lower left of the table.

Type Numbers for Components. Where only a component of a set is to be indicated, the letters "AN" in the prefix are replaced by a component indicator of one or two letters, followed by an assigned number for that component, a modification letter (if applicable), a slant bar, and the set or equipment indicator letters, assigned number, and modification letters of the set for which the component was originally designed. Examples: Radio Receiver R-89A ARN-5A; Radio Transmitter T-47 ART-13. The component indicator is derived from, and interpreted by, the Table of Component Indicators in Appendix III.

The meaning of the various elements of a component type number is explained in a manner similar to that used to explain the type number of a complete set.

In case a component developed for one set is later used in another set, the component will continue to bear its original nomenclature assignment, thus indicating the purpose for which it was originally developed and avoiding more than one nomenclature for a given component. Example: Radio Transmitter T-47 ART-13. The type number indicates that it is the forty seventh radio transmitter (disregarding lettered modifications of preceding transmitters) to be assigned nomenclature in the AN system and is a part of or is used with Radio Transmitting Set AN ART-13. However, Radio Transmitter T-47 ART-13 is also a part of Radio Set AN ARC-8, yet it retains its original nomenclature.

In cases where a component is generally employed with several sets, only such of the set or equipment indicator letters will follow the slant bar as are necessary to indicate the extent of use. Examples: Assume that a headset is designed so that it is suitable for use in several types of installations and can be used for radio telephone, and telegraph. Such an item might be indicated as follows: Headset H-16 U. A motor generator designed to be used with several airborne radar sets is designated Motor Generator PU-7 AP. A test set designed to be used with several airborne radar navigation sets would be indicated as follows: Test Set TS-10 APN. A test set designed to work specifically with a certain airborne radar navigation set would be indicated as follows: Test Set TS-477 APN-19, which would indicate that the equipment was originally designed to be used with Radar Beacon AN APN-19.

Type Numbers for Major Units. The type number for an independent major unit (equipment of military design which is not part of nor necessarily used with a set) or a group of items when less complete than a set, consists of a component indicator; a number; modification letter, if any; the slant bar; and such of the set or equipment indicator letters as apply. Example: Switchboard SB-5 PT would be the type number of a portable telephone switchboard for independent use. SB is the component indicator for a switchboard and PT indicates that it is a ground portable telephone equipment.

In any combination of set or equipment indicator letters, whether it consists of one, two, or three letters, the letters always indicate information in the standard sequence; installation, type of equipment, and purpose. If only one letter is used, it indicates installation. Two letters indicate installation and type of equipment.

Parentheses Indicator. A type number with parentheses, ( ), following the basic type

number is used to identify an article generally, when the need exists for a more general identification than that provided by nomenclatures assigned to specific designs of the article. Example: AN GRC-5 ( ), AM-6 ( ) GRC-5, SB-9 ( ) CG. A specific design is identified by the plain basic type number, the basic type number with a suffix letter, or the basic type number with an experimental indicator in parentheses: Examples: AN GRC-5, AN GRC-5A, AN GRC-5 (C-1), AM-6B GRC-5, SB-9 (XO-3) GG.

3. SIGNAL CORPS NOMENCLATURE SYSTEM

Composition

The old Signal Corps Nomenclature System likewise adhered to the principle that nomenclature consists of a name followed by a type number. Again, the name portion is terminology of standard engineering usage. Examples: Radio Set SCR-522, Radio Set SCR-399, Telegraph Terminal Set TC-22, Telephone EE-8-A, Radio Transmitter BC-375.

The type number consists of one, two, or three letters followed by a number. In general, the letters are abbreviations. Thus, SCR for Signal Corps Radio, BC for Basic Component, and LS for Loudspeakers. This is by no means always true and a thorough familiarity with the system is gained only through long association. No attempt is made to describe the system thoroughly, but rather to present a brief description of it.

Some of the more frequently encountered indicators or letter designators used in the Signal Corps System are interpreted below.

A complete list of such designators and their meanings, appears in AF Technical Order T.O. 16-50-13. A cross index of type numbers, item names, and stock numbers appears in SIG 5-1 section of the Department of the Army Signal Supply Catalog.

The reader may note that in some instances the designators used in the Signal Corps system are identical with some component indicators in the AN system, indicating an apparent source of conflict. This is an apparent contradiction of one of the requirements of the AN system as stated in paragraph 3, a, (4) above. Actually, no confliction exists, due to one or more of the following considerations:

Any type number in the AN system always contains a slant bar ( ) with at least one letter following it. No slant bar is used in type numbers in the Signal Corps system.

In cases where the names of the items differ widely, conflict is avoided by the name. Thus in the Signal Corps system, "C" indicates Coil (induction) and the name associated therewith may be "Coil" or "Transformer"; in the AN system "C" indicates Control Articles which are never of such a nature to be confused with a coil.

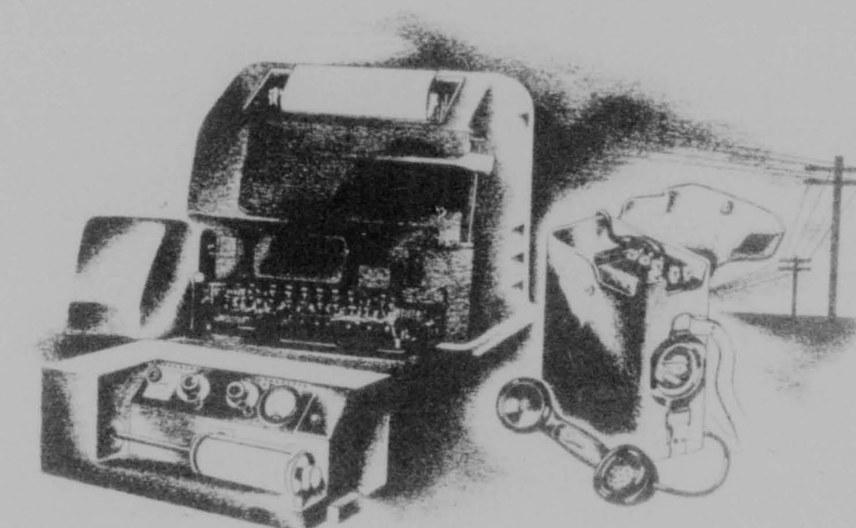
If the names are identical, or likely to be similar, a new block of nonconflicting numbers is used in the AN System. Thus, for the indicator "BA", Battery BA-1 through Battery BA-149 are common to the old Signal Corps System; whereas Battery BA-200 U was the first such battery to be assigned nomenclature in the AN system.

As in the AN system, a type number with parentheses, ( ), is used to identify an article generally. Thus, Radio Set SCR-399 refers to a specific set, as does Radio Set SCR-399-A; whereas, Radio Set SCR-399- ( ) refers to all models of the set.

SIGNAL CORPS NOMENCLATURE

BA — Primary batteries (dry)
BB — Storage batteries
BC — Receivers, transmitters, control boxes, etc. (Radio)
EE — Telephone, Telegraph and Signal Lamp Sets
FT — Fittings, mountings, clamps, etc.
HO — Shelters
HS — Headsets
LS — Loudspeakers
P — Headsets
R — Telephone receivers
RL — Reel Mechanism
SCR — Radio Sets and complete assemblies
SCS — Extensive Communication Systems
TC — Central Office Sets (wire)
TG — Telegraph Instruments
TC — Transmitter Tuning Units

CHAPTER 2 - WIRE COMMUNICATIONS



SECTION 1 - PRINCIPLES OF TELEPHONY

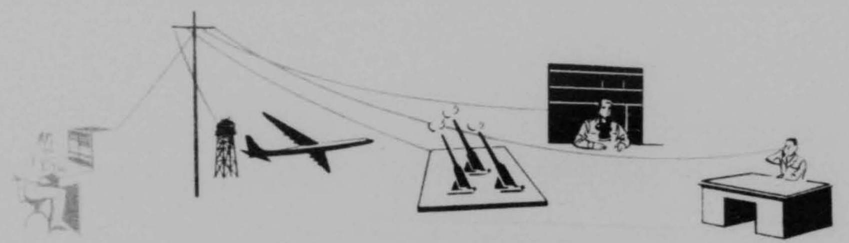
1. GENERAL

Wire telephone communications became an actuality when electrical impulses created by the human voice were first transmitted over a metallic circuit between two distant points. Today, as a result of constant research and development, wire communication has become a primary means of binding the civilized world together.

Likewise, wire communication has become a necessary implement for the successful accomplishment of military operations. When telephone and telegraph were first adopted in military communications systems to meet the requirements of existing tactical conditions, they were restricted to short-range facilities, requiring minimum equipment designed for small combat units. Today, however, as the tactics and techniques of modern warfare have changed, so have the military practices in the employment of wire communications. Present military wire systems are closely patterned after those of commercial companies with modifications and revisions in wire and wire equipment designed to meet the requirements of varying combat conditions. Wire lines used in conjunction with radio links will meet the communications requirements of most tactical situations.

In comparing wire with radio, advantages common to both are found. Technically, the principle of transmission is the same, except for the medium of the transmission path. Tactically, they differ in their employment. However, it is well to remember that wire and radio employed together form the basis of military communications systems.

While wire communications may not have the glamor which is associated with radio, it plays an extremely important part in any



system of military communications. It requires considerable time and planning by the communications officer to make the best use of the facilities available.

Proper employment of these facilities will increase communications security, relieve a great part of the traffic load from the radio system, and permit a more rapid handling of messages.

2. CAPABILITIES AND LIMITATIONS

The quality of service rendered an organization is governed by the capabilities and limitations of wire lines and equipment. Like radio, there are numerous factors which permit or restrict the use of short or long distance wire communications. The more important factors which affect the employment of wire lines are the following:

First, consideration must be given to the electrical characteristics of metallic conductors. There are electrical properties which exist in all conductors when an electromotive force is impressed on them. These properties tend to resist or impede the passage of a message over them, and therefore must be given consideration when planning the use of wire.

Second, consideration must be given to the physical and mechanical characteristics of the wire. These characteristics are also related to the electrical characteristics of the wire. In this category are included the size of the conductor and its mechanical strength.

Third, consideration must be given to the type and size of the tactical organizations to be served by the installation. This consideration, although nontechnical, does affect the type of wire to be employed and the number of circuits that will be installed.

The final consideration is that of personnel. Satisfactory and reliable service can be provided only if the installing, operating, and maintaining personnel know their work. The solution then, is to employ well-trained and experienced personnel. The communications officer must bear this consideration in mind in facing any one of the many communications problems.

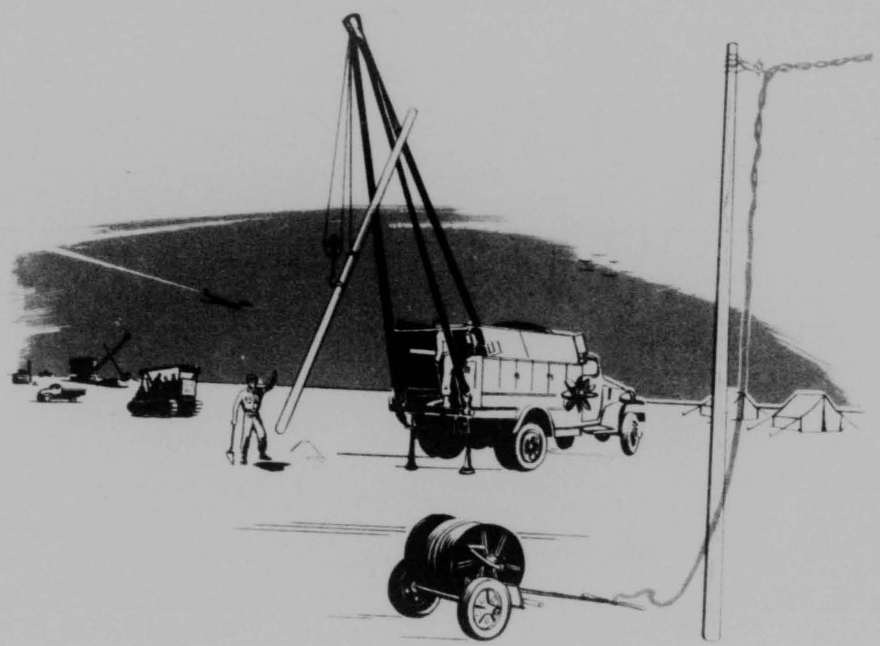
It is these factors which have been briefly discussed that determine the technical capabilities and limitations of wire communications. To these must be added consideration of the principles of communication.

Of the electrical means of communication, wire is generally the simplest since the medium of transmission is physical. Telephone and related systems employed tactically are basically simple circuits; the equipment is not complex.

Well-constructed wire communications facilities are reliable. They are not affected by climatic conditions, nor are they subject to mechanical or electrical failure to any great extent.

Wire is considered as the most secure means of communication. Security is here used in a relative sense. As long as wire lines and terminal equipment are located in friendly territory, there is little danger of interception of messages by an enemy. Traffic is not broadcast as it is when certain types of radio are employed, and, as a result, the only possibility of intercepting messages transmitted over wire comes from enemy agents who may be able to gain access to transmission lines.

The wire systems installed determine the degree of flexibility of the medium. Adequate advance planning will usually provide for



flexibility. Line construction will follow the axis of communication, and will, normally, satisfy military needs. Terminal equipment may be installed which will be adequate even after the original using unit moves away. The medium may be used for voice, telegraph, teletypewriter, or facsimile transmission, or for combinations of several or all of these.

In many respects, wire may be considered to satisfy the principle of mobility since any military wire equipment may be installed in trucks or trailers. Transmission lines such as field wire, rubber-covered cable, and spiral-four cable can be constructed rapidly. While wire cannot match radio as a communication means for mobile units, such as aircraft or tanks, for headquarters which may move from time to time, it is possible to install wire facilities rapidly enough to consider that it is a mobile means of communication.

3. TELEPHONE TRANSMISSION OF SPEECH

General

Because of the small amount of energy contained in the normal talking voice, the distance of satisfactory reception between the individual to whom communication is directed and the speaker is restricted. When the intervening distance becomes too great for face to face conversation, the telephone supplies the simplest medium of transmission for voice communication. The purpose of a telephone, like that of radio, is to extend the range of voice communication between individuals. To accomplish this, the telephone system must first convert the energy of the speech sound wave in air to a corresponding electrical wave which may be transmitted over the intervening wires, and then to reconvert the electrical energy into sound energy so that it may be understood. The tele-

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phone transmitter is the device which converts the sound wave energy into electrical energy and back again to sound energy. Other essential parts of modern telephone sets are the induction coils, capacitors, the hook switch, signaling equipment, and a ringer. These will be described in turn in succeeding paragraphs.

The original telephone, invented by Alexander Graham Bell in 1876, consisted of a carefully constructed instrument which was used both as a transmitter and as a receiver. Neither a battery, nor signalling equipment was employed. Figure 2-1 illustrates the circuit of two such units.

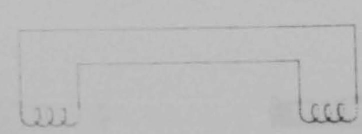


Figure 2-1 Simple Telephone Circuit

At the speaker's station, the sound waves of the voice strike the metal diaphragm of one unit; the alternate condensations and rarefactions of the air set the diaphragm in vibration. Behind the diaphragm is a permanent magnet, the lines of force leaving the north pole of the magnet pass through the winding, through the diaphragm, and return to the south pole of the magnet. A review of magnetism reveals that the number of lines of force depends upon the width of the air gap as well as the metal in the magnetic path. As the diaphragm moves in and out under the influence of the sound waves, it varies the length of the air gap between the diaphragm and the permanent magnet. The vibration of the diaphragm causes corresponding changes in the number of lines of force which pass through the receiver winding; this results in the winding being cut by a varying magnetic field, or an increasing or decreasing number of lines of force. The changing magnetic field establishes a varying electromagnetic force in the winding. This induced voltage has wave characteristics that correspond to the impressed sound wave.

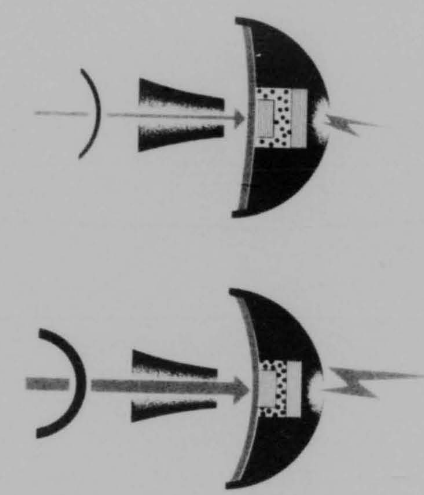
Figure 2-1 shows that the windings of both units are connected in series so that any current which flows through one winding must flow through the other winding.

The varying current which has been generated at the speaker's end of the circuit will pass through the winding at the distant end of the line. In so doing, it will set up a field that alternately strengthens and weakens the field of the permanent magnet at the distant end. The varying magnetic field exerts a varying pull upon the receiving diaphragm with the result that the receiving diaphragm will vibrate in unison with the diaphragm at the transmitting end, and thereby reproduce the original sound. Because of the losses in the transmission line and in the telephone units, the receiving diaphragm will vibrate with less amplitude, and produce a less intense sound than was originally put in at the sending end.

This discussion of the Bell instrument has been included because the principle of operation applies to modern telephone receivers and to the sound-powered telephone discussed in paragraph 6. Modern telephone transmitters are described below.

Telephone Transmitters

In the early stages of telephone development, it was found that electrical energy generated by a diaphragm moving in a comparatively weak magnetic field was insufficient for the transmission of speech over any great distance. Even by using stronger magnets, the best possible diaphragms, and louder sounds, voice transmission was limited to rather short distances. One year after the invention of the original telephone, the Blake transmitter was introduced. It worked on the principle of a diaphragm varying the strength of an already established electrical current, in contrast to the generation of electrical energy by means of electromagnetic induction. This type of transmitter is very similar to a valve, since it regulates the flow of current from some external source.



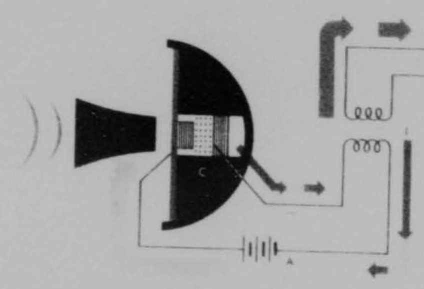


Figure 2-2 Simple Telephone Transmitter Circuit

The principle of the transmitter may be better understood by referring to Figure 2-2. Direct current from battery A flows first through a cup of carbon granules C, then through the primary winding of an induction coil I, and back to the negative terminal of the battery. The function of the induction coil will be discussed at a later time.

One side of the cup C rests against a small carbon disk, which is rigidly connected to the transmitter diaphragm. As the diaphragm vibrates, it varies the pressure upon the carbon granules, causing them to make better or poorer contact with each other. This causes fluctuations in the value of the direct current maintained in the circuit by a battery. These varying fluctuations, even though they are represented by varying values of direct current, establish, by transformer action, an induced alternating electromotive force in the secondary of the induction coil. The alternating electromotive force in turn causes an alternating current to flow in the series circuit consisting of the line and the two receivers. Figure 2-3 illustrates transmitters used at the ends of a simple telephone circuit.

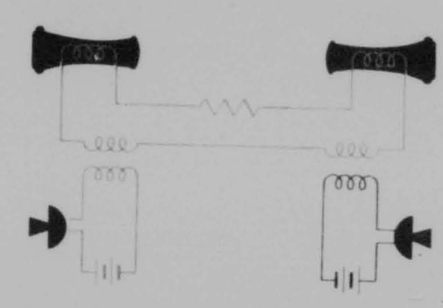


Figure 2-3 Use of Transmitters in Simple Telephone Circuit

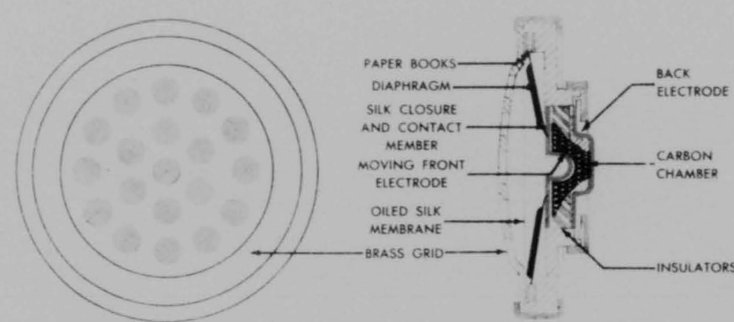


Figure 2-4 Modern Transmitter Unit

It can be seen from Figure 2-3 that when a person speaks into a transmitter, the voice currents which result must pass through the windings of his own receiver. This sound heard in the receiver (caused by vibrations picked up from the transmitter of the same telephone unit) is called "sidetone."

The operation of a telephone transmitter depends upon the vibration of the diaphragm. The vibration of the diaphragm is caused by the variation in the pressure of the sound wave striking it. Figure 2-4 illustrates a cross section of a transmitter unit which is widely employed in current telephone practice.

The electrical circuit passes from the moving front electrode, through the carbon chamber, to the back electrode. The conical bell-shaped carbon chamber is used so that sufficient contact force exists between the carbon granules and the electrodes, regardless of the position in which the transmitter is held. For this reason, the transmitter will ngnt magnet; the lines of magnetic force operate satisfactorily in any position. Transmitters possessing this feature are called "nonpositional." The transmitter is also of the direct action type; that is, the movable element is attached to the diaphragm, and in addition to exerting the variable pressure, also serves as an electrode. As the drawing shows, this curved electrode is attached to the center of a conical diaphragm, forming the front center surface of the bell-shaped carbon chamber. The diaphragm is made of an aluminum alloy 0.003 inch thick and has ridges to increase its stiffness. Paper books, which consist of a number of thin paper rings, support the diaphragm at its edges without restricting its movement. The carbon chamber is closed on the front side by a silk covering clamped upon the flange of the front electrode. A light, spoked copper contact member, also clamped under the front electrode, provides a flexible connection between the front electrode and the metal frame. The fixed back electrode is held in place in the frame by a threaded ring; it is insulated from the frame by a fiber washer and a ceramic insulator, which also forms part of the surface of the carbon chamber. The surfaces of both front and back electrodes are gold plated where they make contact with the carbon granules. The perforated brass plate, or grid, in Figure 2-4 protects the vibrating parts from mechanical injury. Moisture is kept out of the working parts by an oiled silk membrane placed between the brass grid and the diaphragm. When new, the transmitter unit has a resistance of about 35 ohms.

Figure 2-5 illustrates the manner in which the transmitter unit is mounted in a shell when used as part of a modern telephone

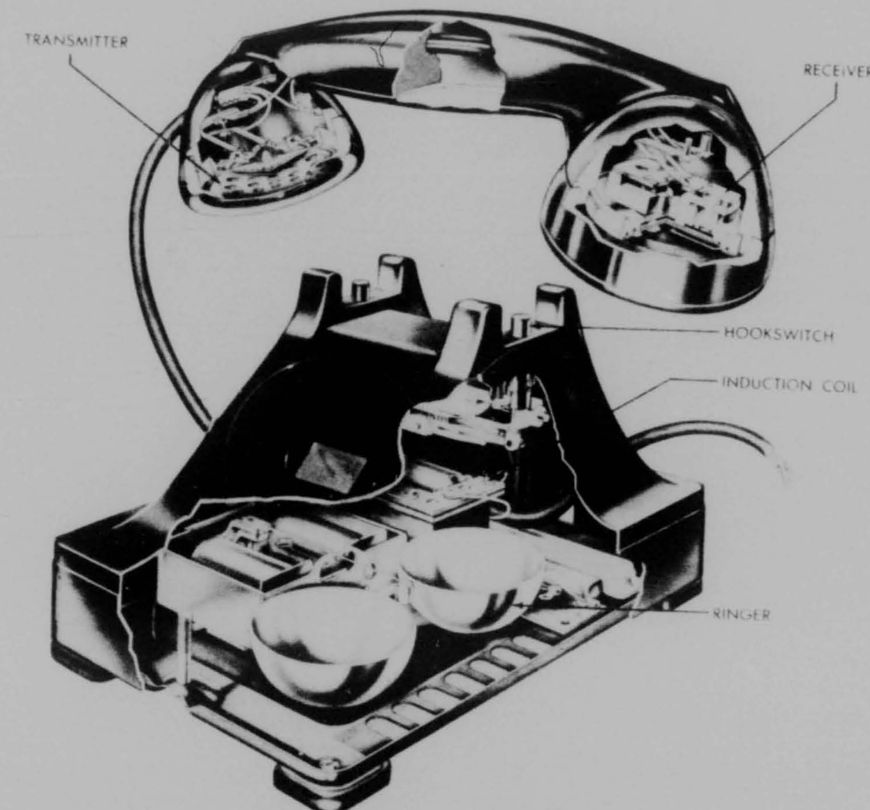


Figure 2-5 Cutaway of Telephone Desk Set

handset. The transmitter unit may be removed by unscrewing the transmitter cap or mouthpiece. This figure also shows how the contact springs press against the contacts of the transmitter unit. The transmitter mouthpiece is made of the same plastic material as that of the receiver shell and case.

Telephone Receivers

There has been no fundamental change in telephone receivers comparable to that which has been made in transmitters. Consequently, the theory of the operation of the original Bell instrument applies to present day equipment.

The earlier forms of the telephone receiver were equipped with a permanent bar magnet as illustrated in Figure 2-6.

The efficiency of this instrument was greatly increased by the use of the horseshoe magnet, as illustrated in Figure 2-7. Here the length of the magnetic path is greatly shortened, since the magnetic lines of force, after passing through the airgap, pass from one pole to the other through the diaphragm only.

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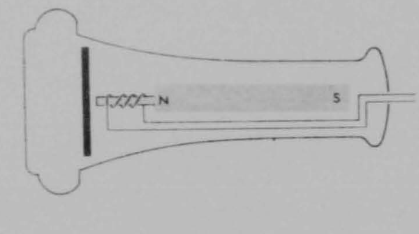

Figure 2-6 Telephone Receiver

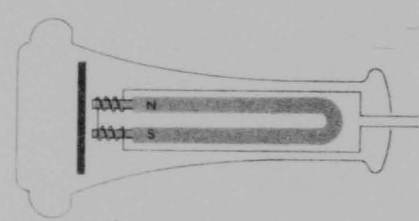

Figure 2-7 Telephone Receiver with Horseshoe Magnet

Modern telephone receivers are equipped with permanent magnets which normally are not impaired by jarring or other abuse. A permanent magnet not only increases the amplitude or vibration when voice currents are flowing in the windings, but also prevents the diaphragm from vibrating at twice the voice frequency. This principle is illustrated in Figure 2-8.

When a diaphragm is held near an electromagnet consisting of a soft iron core and a winding, the diaphragm is attracted by the electromagnet regardless of the direction of the current in the windings. If, as in Figure 2-8, an alternating current were passed through a coil wound around a soft iron core, the diaphragm would be attracted during each half cycle. Such a receiver would be useless, since the sound wave produced obviously would not be identical with the electric wave that produces it. But if, as in Figure 2-8, a permanent magnet is used as the core, the electromagnet merely increases or decreases the pull of the permanent magnet. The permanent magnet exerts a constant pull upon the diaphragm, when the current through the receiver winding is in such a direction as to set up a magnetic field that will aid the magnetic field of the permanent magnet, the diaphragm moves inward toward the magnet. Conversely, when the direction of the current is reversed, the diaphragm moves outward. The diaphragm then moves both inward and outward from its neutral position, and produces a sound wave corresponding in frequency and amplitude to the impressed electrical wave.

Remember that if it is necessary to permit the flow of direct current through a receiver winding, the receiver should be connected in such a manner that the field produced by the direct current will aid the field of the permanent magnet. Such a process is called "poling." The word "poling" is also used when other types of connections are made; for example, "poling the batteries in a series connection" so that their voltage will be additive.

One of the latest receiver unit types is shown in Figure 2-9. Three comparatively new magnetic alloys are used in its construction; the receiver unit is designed so that it can be mounted in several different types of telephone instrument. The receiver winding

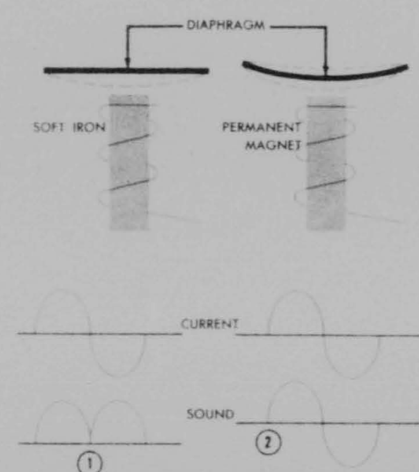

Figure 2-8 Operation of Telephone Receiver

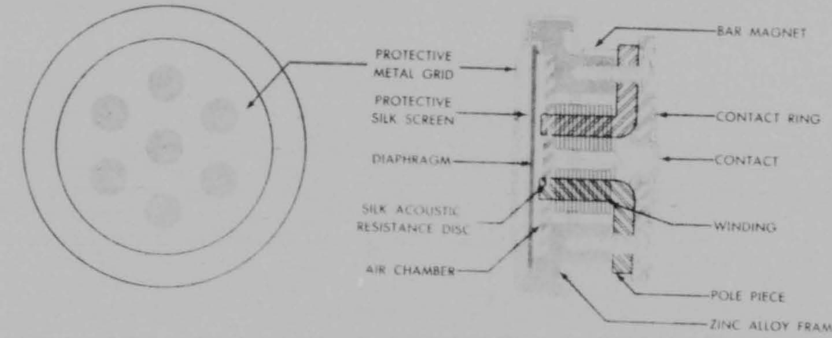

Figure 2-9 Modern Handset Receiver

is wound around two permalloy pole pieces, shown in Figure 2-9. The pole pieces are welded to a pair of very strong, cobalt-steel bar magnets. The whole assembly is fastened to a zinc-alloy frame.

The diaphragm, which is made of special steel alloy, is unclamped, and, as can be seen from Figure 2-9, rests upon a ring-shaped ridge. The whole unit is held together by a brass clamping ring. Upon the back of the unit are mounted two silver-plated contacts for electrical connections. Figure 2-5 illustrates how this receiver unit rests in the receiver shell when used with a standard desk-stand. If trouble develops, or when necessary for testing purposes, the receiver unit may be removed by merely unscrewing the receiver cap. When the receiver cap is screwed on tight, it exerts a pressure on the receiving unit, forcing the two silver-plated contacts against two contact springs which are connected to the external wiring. The receiver and transmitter described are of recent design; however, many of the older types are still in everyday use. Different designs are used for operators' chest sets and linemen's test sets. The principles involved, though, are essentially the same in all cases.

Telephone Induction Coils

A telephone induction coil is a transformer which is efficient over a wide range of voice frequencies. The discussion in this text will be limited to the types of induction coils which are commonly employed in military communications.

There are two general types of induction coil: the closed-core type and the open-core type. The closed-core type is more efficient because the iron core forms a closed loop around the coil. It provides a better magnetic return for the lines of force than does the open-core type, which requires that the lines of force complete their circuit through the long air gap between the ends of the magnet. The coil consists of insulated copper wire wound around a laminated silicon-steel core. The employment of a laminated core minimizes power losses caused by eddy currents in the core. Most induction coils used in telephones have either two or three windings, the ends of which are brought out to terminals mounted over the core.

Induction coils are used in telephone systems to separate physically, and, at the same time, to couple inductively two electrical circuits. The manner in which a telephone transmitter causes a variation in the value of a steady direct current already has been explained. The variation in current may be considered as two separate currents. The first of these is the steady value of the current supplied by the battery, and the second is the fluctuating current caused by the voice which is superimposed upon the steady value of the direct current. Since the induction coil is a transformer, a steady current flowing in its primary will not cause a voltage to be induced in its secondary. The superimposed voice currents, since they are changing in value, will induce corresponding voltages in the secondary. The transmission efficiency of

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the telephone set is also increased by stepping up, through transformer action, the voice frequency voltages originating in the transmitter circuit. These factors will be discussed more fully in the study of telephone station circuits.

Telephone Capacitors

A capacitor may be described briefly as a device which acts like an open circuit to direct current, but which permits the passage of alternating current. With a fixed capacitor in a circuit in which an alternating current of varying frequency is flowing, the impedance of the circuit varies inversely with the frequency. In other words, as the frequency of the applied alternating voltage increases, the impedance of the capacitance decreases and as the frequency of the alternating voltage decreases, the impedance will increase. Voice frequency currents transmitted over a telephone system are considered to be essentially between 200 and 2,700 cycles per second; the ringing currents used by the operator to operate the signaling device are in the neighborhood of 20 cycles. A given capacitor will offer much more impedance to the low frequency ringing current than to the high frequency voice currents. If it is remembered that a larger capacitor is required to pass ringing currents, it will be much easier to trace the separate paths of ringing and voice currents in circuits to be encountered in later sections of this book.

The two general types of capacitors used extensively in telephone practice are either paper or mica capacitors. The terms "paper" and "mica" are derived from the type of separator employed in the construction of the capacitor. The separator is called the "dielectric."

Telephone Hookswitch

The telephone hookswitch is a device that will break or open the circuit when the telephone is not in use. Its purpose is to prevent any unnecessary drain on the power supply. The hookswitch is simple and automatic in its operation since merely lifting the receiver from its hook or cradle closes the contacts. In addition, in common-battery telephone circuits, closing or opening the hookswitch contacts automatically signals the operator that a call is to be placed or has been completed. There are several types of hookswitch and numerous spring arrangements sometimes referred to as "pile-ups;" the different arrangements are used for extra features in telephone circuits. A type of hookswitch in common use is the plunger type. (See Figure 2-5). This hookswitch depends upon the weight of the handset to depress two plungers that push against the springs, thereby opening the circuit in the manner previously described.

Signaling

Telephone systems must provide some means whereby a telephone subscriber may call or signal the operator when it is desired to make a call. The signaling equipment is in addition to the equipment required to transmit the voice signals. Signaling equipment is also required by the operator when it is necessary to call a subscriber. In order to accomplish signaling, a generator capable of providing the ringing current and a ringer assembly must be added to the system. For local battery systems a hand-cranked generator, described below, is used in telephones and small switchboards. Larger local-battery switchboards are provided with a reed vibrator. Common-battery systems employ a 20-cycle rotary inverter.

The magnetic field of a hand generator is supplied by a combination of two to five U-shaped steel permanent magnets arranged with like poles on the same side. These magnets are provided with cast-iron pole pieces (Figure 2-10). End plates which contain bearings are secured across the ends of the pole pieces and in these bearings an armature is mounted.

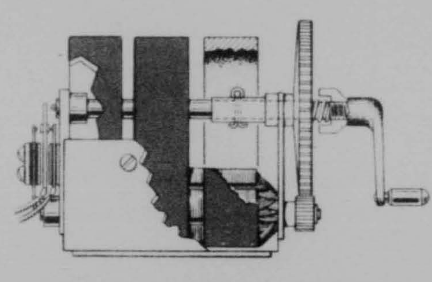

Figure 2-10 Gear & Crank for Hand Generator

The fewer the bars in the permanent magnet, the greater will be the number of turns in the armature winding, which range from about 3,000 turns for a three-bar generator, to 1,700 turns for a five-bar generator. In a particular type of generator, one end of the winding is connected to the armature core, and the other end connected to a pin set in the axis of the armature shaft. This pin is insulated from the rest of the shaft. A flat spring presses against the pin and completes the armature circuit to one terminal of the generator, while a connection to the generator frame acts as the other terminal.

Telephone Ringers

Figure 2-11 illustrates a common type of telephone ringer.

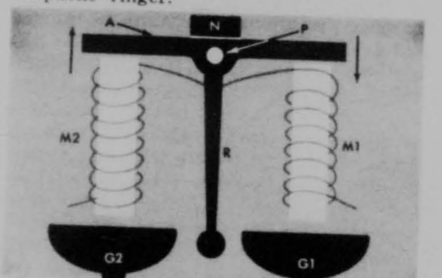

Figure 2-11 Telephone Ringer Circuit

This device operates on the 20-cycle ringing current generated either by a hand generator or a ringing machine.

The theory of the ringer can be more readily understood by referring to Figure 2-11. N represents the north pole of the permanent magnet. The permanent magnet is mounted very close to the center of the armature, and induces a south pole at the center of the armature. Assume that the 20-cycle ringing current is passing through the windings and that its direction during a half-cycle is as illustrated. This makes the upper end of M1 a south pole and the upper end of M2 a north pole. The armature will rotate in the direction indicated about its pivot P, striking the tapper against G2. During the next half-cycle of the ringing current, the direction of current flow is reversed, reversing the direction of rotation of the armature, so that the tapper strikes G1. This action is repeated with subsequent cycles of the ringing current. The name of "polarized ringer" is applied to this type of ringer, since it has a permanent magnet. Windings with resistances ranging from 250 to 2,500 ohms are constructed, with a 1,000-ohm ringer being the most common. The impedance of a 1,000-ohm ringer to average voice current frequencies is approximately 30,000 ohms, and the presence of a ringer across the line during normal conversation does not cause appreciable transmission loss. However, some telephone circuits provide for removing the ringer from the line during the period of conversation by employing the action of contacts in the hookswitch.

SECTION - 2 TELEPHONE SYSTEMS

1. IDENTIFICATION OF TELEPHONE SYSTEMS

There are two types of military telephone systems: the **local-battery** and the **common-battery systems.** The common-battery system may be either manual or automatic. These systems plus the sound-powered telephone will be described in this section.

To identify local-battery and common-battery telephone systems, the distinguishing features of each type of system must be kept in mind.

In **local-battery telephone systems,** the electrical energy for the operation of the transmitters is furnished by dry cells located within each telephone instrument. Signaling is accomplished by cranking a hand generator

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which provides an alternating current to operate the ringers and drops. When the telephone is not in use, no voltage is applied to the line. For this reason, local-battery lines are said to be dry.

On the other hand, in **common-battery systems** all DC voltages are supplied by a large storage battery located at the common-battery switchboard. For the purpose of this textbook, it is sufficient to say that a battery of 24-volt potential is applied at all times to each individual line. It is used to furnish current for the operation of the transmitters, for signaling purposes, and for supervision. Common-battery lines are said to be wet because there is a voltage applied to them at all times.

2. CAPABILITIES OF TELEPHONE SYSTEMS

The current required from each battery in a local-battery telephone is slight and intermittent, hence dry cells are as well suited for this duty as any other type of cell. But from an economic standpoint, dry cells are one of the most expensive sources of electrical energy. Furthermore, their life is short, they deteriorate while idle, and their voltage is not constant. When used in telephones, their maintenance requires frequent visits to each instrument to test the battery and replace exhausted cells. The service between stations in the local-battery system is not uniform, since a station with a partially exhausted battery may be connected with one having a fresh battery. The inclusion of batteries and a hand generator in each telephone results in an instrument which is bulky and complex. The turning of the hand generator to signal the operator requires conscious effort on the part of the subscriber. Failure on the part of the subscriber to signal the switchboard operator that his call is completed (ring-off) increases the work of the operator. The restoration of the drops and the necessity for cutting in to supervise also add to the operator's work.

However, in spite of these disadvantages there are certain advantages that make this system very usable in military communications systems. There are many instances where this equipment may be used to much greater advantage than common-battery systems. Since a common-battery system requires a higher voltage battery to supply sufficient current for transmitter operation, a better quality of outside plant construction is required to minimize leakage and subsequent loss of power. Furthermore, common-battery switchboard equipment is far more complex and delicate than is the local-battery equipment. Local-battery transmission is superior to that of common-battery over long lines having relatively high resistance. From the standpoint of condition of outside plant, reliability of switchboard equipment, and volume of transmission, common-battery equipment is not well suited for military field telephone systems, which are more or less temporary. However, local-battery equipment is well suited for this type of operation.

The use of the common-battery system overcomes some of the objections to local-battery equipment. By furnishing all current used in the system from a centrally located battery, the drain is sufficient to warrant the use of storage batteries, which are efficient when properly maintained. The cost of the energy to recharge the storage battery is a great deal less than the cost of the purchase of dry cells to give the same service. In addition, it does not require that each station be visited periodically by a maintenance man and thereby effects a consideration saving in man-hours. Since automatic signaling of the operator is inherent in the common-battery system, the magneto is not required in the common-battery telephone. With the removal of the magneto and battery from the telephone instrument a simpler, smaller, and neater instrument results. As the operation of the common-battery telephone will be explained more fully in a later section, it is sufficient to say that lifting the handset will complete a signaling circuit notifying the operator that the subscriber desires to place a call. Returning the handset to the hook signals that the call has been completed. Automatic signaling and supervision not only simplify the routine for persons using the telephone, but they reduce the operating work to such an extent that a signal operator can handle many more lines on a common-battery switchboard and still furnish better service.

Post installations are of more permanent nature and are better suited for the application of the common-battery equipment than are most of the field installations.

3. LOCAL-BATTERY TELEPHONE SYSTEM

General

Local-battery telephone systems consist of telephone instruments, switchboards, and transmission lines. The most commonly used local-battery telephone, EE-8-( ) and representative local-battery switchboards will be described in the following paragraphs. Transmission lines will be included in a later paragraph.

Local battery antisidetone telephones such as the EE-8-( ) are used on point-to-point circuits and on loops to magneto switchboards. They are also used on long loops to common-battery switchboards where, because of the high resistance in the transmission line, an adequate amount of direct current does not reach the microphone. They also may be used on short loops to common-battery switchboards if common-battery telephones are not available.

Telephone EE-8-( )

With good batteries, the direct current through the microphone in the EE-8-( ) telephone will be in the vicinity of 0.06 to 0.07 ampere. A satisfactory grade of transmission will be obtained between two such telephones connected by lines having transmission losses of not more than 30 db.*

(*Transmission losses and gains are expressed in terms of the unit called the "decibel," abbreviated as db. This will be further explained in Section IV.)

Handset TS-9-( ) which is furnished as part of Telephone EE-8-( ) contains a compensated magnetic-type receiver in which the diaphragm is damped and free to move at the edge. This type of receiver produces equally well in all frequencies of the speech transmission band which are important from the standpoint of intelligibility (200 to 3,000 cycles).

The speech transmission loss is caused by bridging a Telephone EE-8-( ) across a 600-ohm line is about 3 db. However, because of resonance between the capacitance and induction elements in the telephone, the impedance of the telephone is very low at 500 cycles and the bridging loss at this frequency may under some conditions be as much as 15 db. It is therefore important to avoid bringing this telephone equipment across circuits using 500-cycle ringing.

Figure 2-12 illustrates the Telephone EE-8-(B).

Transmitting Circuit. The transmitter, receiver, induction coil, and the 0.3-mf capacitor are connected in an antisidetone circuit in which the impedance of these elements and the characteristic impedance of the average line (Wire W-110-B) are so balanced as to reduce the sidetone in the receiver to the proper level. This results in an effective gain since the effect of noise in the vicinity of the transmitter of the receiving telephone is reduced. The user also unconsciously speaks more loudly into the transmitter. This results in effective transmitting gain. On lines shorter than the average, the sidetone is more pronounced and the antisidetone effect is lessened.

Operating the handset switch closes the circuit consisting of the switch, battery, transmitter, and 2-3 section of the induction coil. Since this circuit has a relatively low impedance, large current changes are produced by the transmitter when it is activated by the sound of a voice. These current changes induce relatively high voltages in the entire 1-4 winding of the induction coil and across terminals **L1** and **L2** to which the line is connected.

The antisidetone operation of the circuit results from the electrical balance between the impedance of the 3-4 section of the induction coil in series with the 0.3 mf capacitor, and the impedance of the line circuit consisting of four miles or more of Wire W-110-B connected to terminals **L1** and **L2**. On shorter lines the antisidetone is less pronounced, although still effective.

Receiving Circuit. The induction coil, 0.3-mf capacitor, and receiver are so designed

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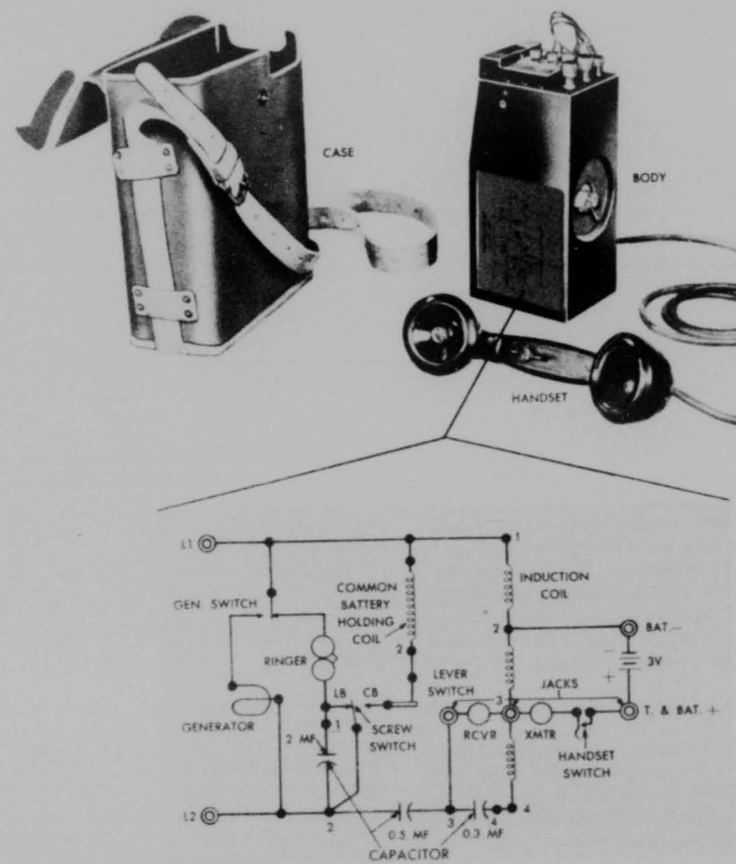

Figure 2-12 Telephone EE-8-B plus schematic

that the greater portion of the incoming line current will flow through the receiver over the voice-frequency range. This results in a maximum signal output.

The 0.5-mf capacitor is placed in series with the receiver to prevent the flow of direct current through the receiver, either from the batteries in the telephone or from the central office battery, when the telephone is connected to a common-battery system. This capacitor also limits 16-cycle ringing current through the receiving circuit and permits the permanent connection of the listening circuit across the line.

The transmission loss through the ringer, or the ringer and the capacitor in series, and the holding coil is negligible because of the high impedance to voice-frequency currents of these elements.

Signaling Circuit. The 1.9-mf capacitor in Telephone EE-8, or the 2.0-mf capacitor in Telephone EE-8-A and EE-8-B, is in series

with the ringer when the screw switch is in the CB (common-battery) position. This capacitor prevents direct current from biasing the ringer and also prevents the ringer from interfering with DC signaling or supervision when the telephone is connected to a common-battery system. The capacitor is short-circuited when the screw switch is turned to the LB (local-battery) position.

Telephone TP-9

This telephone combines the functions of Telephone EE-8-( ) and transmitting and receiving amplifiers which are located in the base of the unit, as shown in Figure 2-13. It is equipped with a transmitting amplifier which gives a fixed gain of 17 db compared with Telephone EE-8-( ) and is capable of providing a maximum power output of 15 db above one milliwatt. Because of this limitation on power output, the maximum gain of 17 db will be available only with talkers whose speech volume is below average. The receiving amplifier provides a variable gain up to about 55 db. The direction of transmission is controlled by the push-to-talk

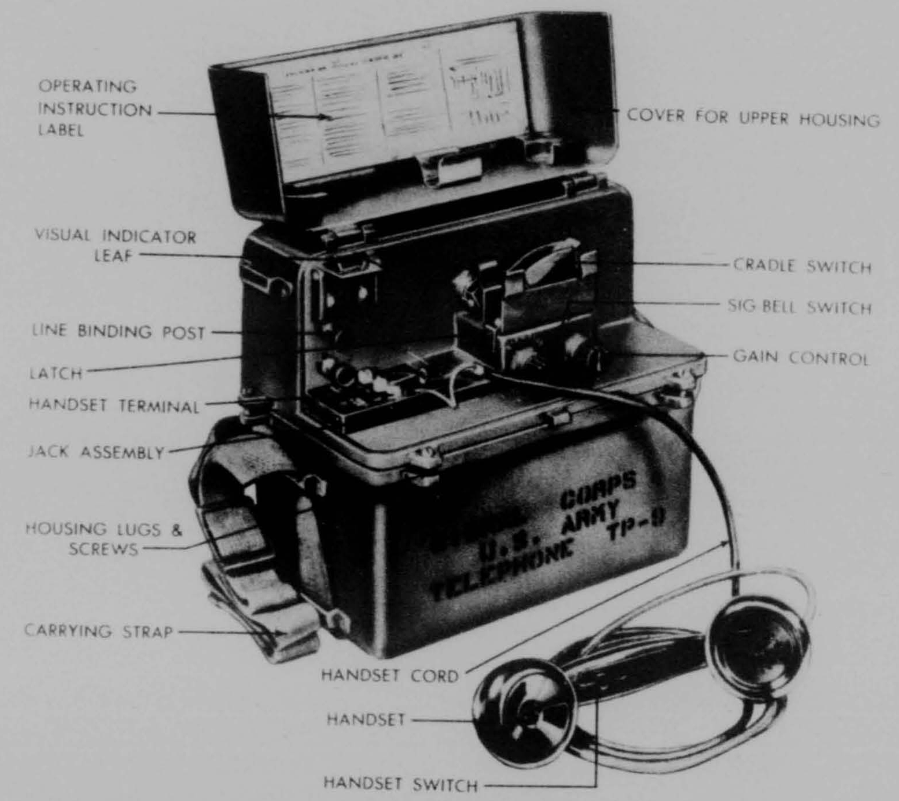

Figure 2-13 Telephone TP-9

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switch in the handset handle. While talking, the receiver circuit is open and the talker neither hears sidetone nor can he hear the distant party if he attempts to interrupt. This telephone cannot be used on common-battery loops since no coil is provided to complete the DC signaling path.

This telephone is intended for use where line losses are so great that transmission with Telephone EE-8-( ) is unsatisfactory. Since it has a power output which is approximately 15 db greater than that of the EE-8-( ), the probability of introducing cross-talk into other telephone circuits and overloading telephone repeaters is materially increased.

The large gains in receiving efficiency which are available will be effective in improving transmission on loops having high attenuation losses, and which are not subject to interference from power circuits or other extraneous sources, and in locations where ambient (acoustic) noise is high.

The high receiving gain of this telephone suggests the possibility of using it for listening in on enemy circuits either through a direct high impedance bridge or through crosstalk in a coupled path.

Local-Battery Switchboards

Switchboard Functions. The necessity of incorporating a switchboard in a telephone system is obvious. It is readily seen that it would be impossible to connect the subscriber's telephone to every other telephone subscriber that he might have occasion to call. This discussion will be limited to the switchboards which are employed in the military communications system. The functions which a local-battery switchboard must perform may be summarized as follows:

Provide a means of interconnecting the local loops and trunks terminated on the switchboard.

Provide a means whereby the operator can be signaled on all lines and trunks terminated on the switchboard.

Provide a means where the operator may talk and listen to the telephone subscribers who are connected to the switchboard.

Provide a means whereby the operator can signal on all lines and trunks terminated on the switchboard.

Provide the operator with a means of supervising calls.

Local-Battery Line Circuits. Each telephone line brought to a switchboard is connected to a separate jack. In order that the operator may be signaled, a line drop is provided in the local-battery switchboard for each line. The electrical circuit composed of the telephone line, the switchboard jack, and the line drop is called the line circuit. One type of line circuit is illustrated in Figure 2-14.

Turning the generator crank of the subscriber's telephone bridges the hand generator across the line, completing a circuit from the hand generator through the winding of the line drop. The ringing current from the generator passes through the winding of the drop, causing the armature to be attracted to the core or the winding. Since the armature is pivoted at point P, the shutter rod will raise and release the shutter. The falling of the shutter, or "line drop", as it is frequently called, provides a visual indication to the operator that the subscriber desires to place a call.

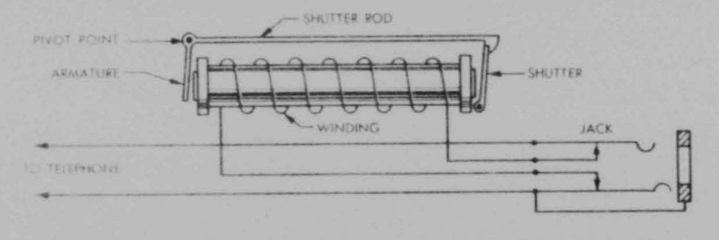

Figure 2-14 Local Battery Line Circuit

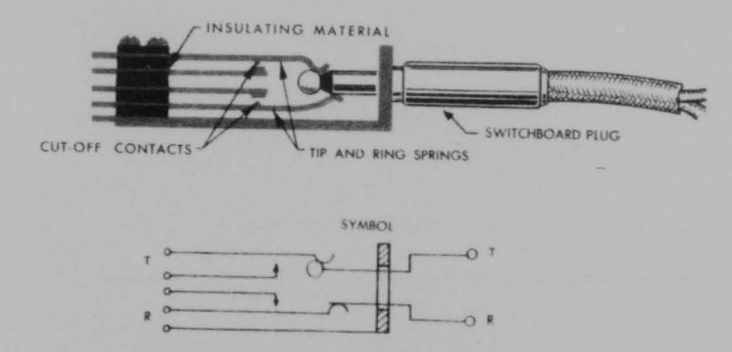

Figure 2-15 Local Battery Switchboard Jacks

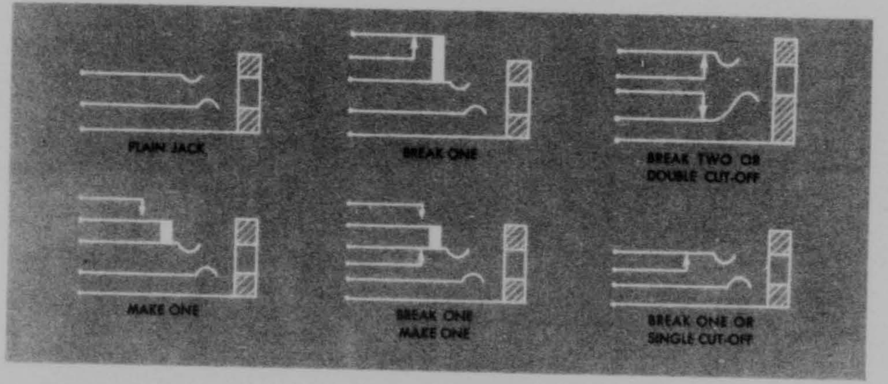

Figure 2-16 Types of Jacks

Drops are made with windings, having several different resistance values. This resistance varies from 80 to 1,600 ohms, with a value of 350 ohms being the most common. The windings do not offer a high impedance to voice currents. Consequently, if they are allowed to remain bridged across the line during conversation a considerable transmission loss would result, since the voice currents would be shunted through the winding. In order to prevent this loss, the circuit to the line drop is opened during the conversation as shown in Figure 2-15. When a switchboard plug is inserted in a jack, the tip and ring springs of the jack are forced apart, breaking the contacts between them and the cutoff springs. Jacks are made with several different combinations, depending upon the circuit in which they will be used. Some of these combinations are illustrated in Figure 2-16.

Types of Local-Battery Switchboards. The smallest switchboards are of the magneto-monocord type. These switchboards are available in capacities from six loops as provided by Switchboard BD-71 up to 12 loops as provided by Switchboard BD-72. The latter switchboard is illustrated in Figure 2-17. The equipment for each loop or trunk is principally a cord, a jack, a drop, and a two-way lever-type key. Ringing from the distant end of the loop operates the drop. The operator's

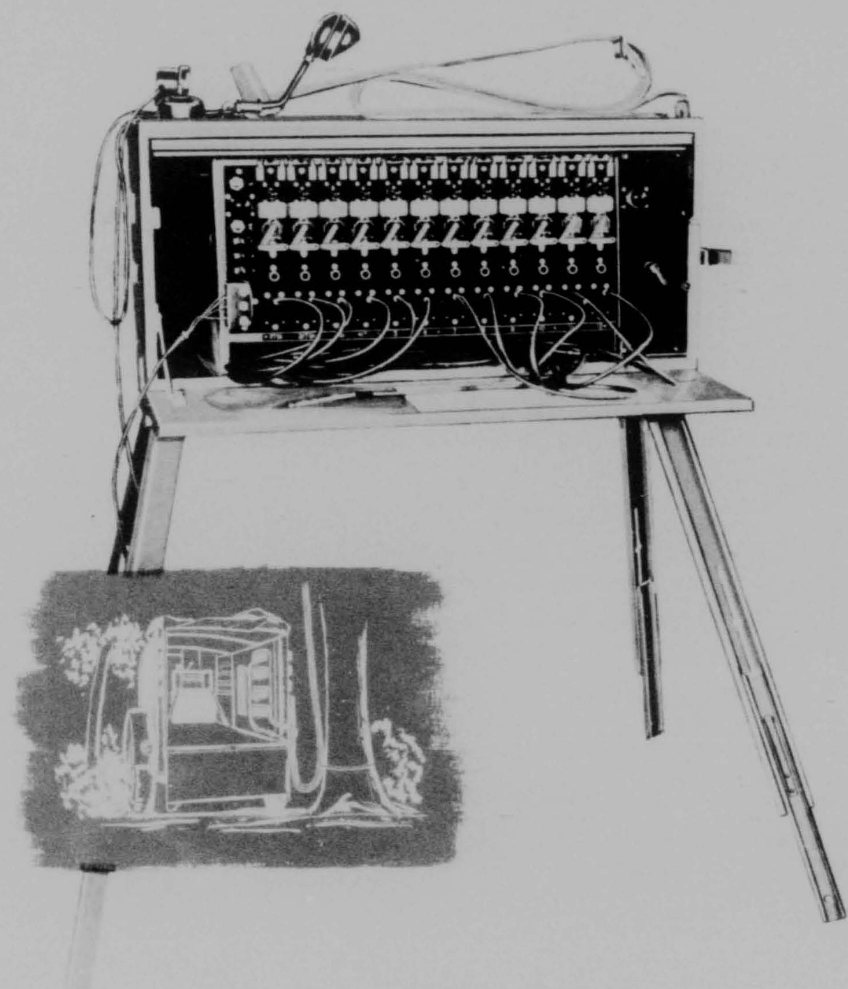

Figure 2-17 Local Battery Switchboard, BD-72

telephone is connected to the loop by the operation of the key switch in one direction. The key switch will remain in this position as long as the operator permits. Operation of this key in the opposite direction permits the operator to transmit a ringing current from his hand generator. The key must be held in the ringing position since it will return automatically to the neutral position. A connection between two loops is established

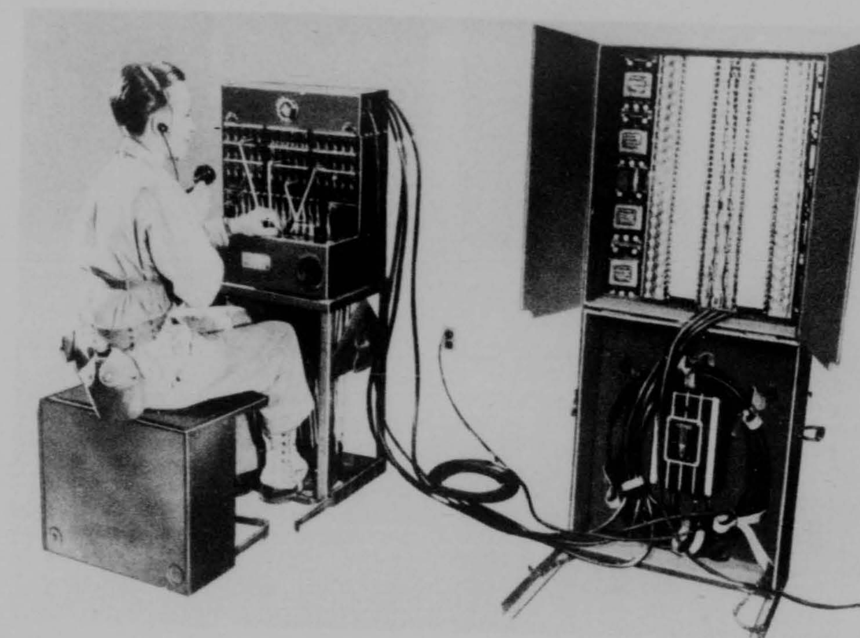

Figure 2-18 Telephone Central Office Set, TC-4

by connecting the cord associated with one circuit to the jack of the other loop.

The switchboards larger than those of the monocord types are of the cord type. Connections through these switchboards are established by cord circuits, terminated in pairs of cords. To establish a connection, one cord of a pair is connected to the jack of the called loop or trunk. Supervisory signals during connections over the cord circuit are indicated by drops or lamps associated with the cords. Signals on loops or trunks, while the cords are disconnected, are indicated by drops or lamps associated with the jacks. Connections to the operator's telephone are established through cord circuit keys. Similar keys are provided in the cord circuits for ringing on the loops and trunks.

The Switchboard BD-96, part of Telephone Control Office Set, TC-4, shown in Figure 2-18 is a local-battery cord switchboard with 40 loops and 12 cord circuits.

4. COMMON-BATTERY TELEPHONE SYSTEM

General

The circuit to be discussed in this paragraph is basic to all common-battery telephones. The circuits used in actual practice may be modifications of this circuit but essentially they remain the same in function. The components of the common-battery telephone are: transmitter, receiver, induction coils, capacitors, hookswitch, and ringer. The hookswitch, transmitter, receiver, and ringer are similar to those employed in the local-battery telephone.

Basic Circuit. The basic common-battery telephone circuit may be developed in a logical manner. Current for talking purposes is fed to the telephone from a central source so that it may be assumed that a battery is connected in some way to the terminals L1 and L2 of the subset. This circuit is called

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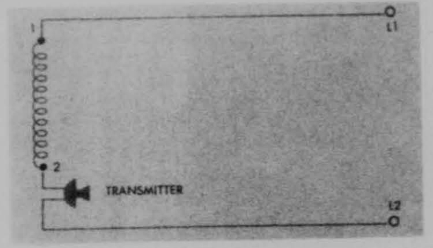


Figure 2-19 Primary Circuit of Telephone

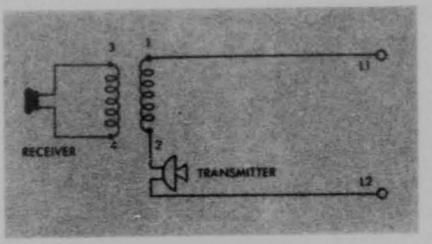


Figure 2-20 Primary & Secondary Circuits of Telephone

the "transmitter" or primary circuit and is illustrated in Figure 2-19. The receiver is coupled to the primary circuit by means of the secondary winding of the induction coil. This circuit is called the "receiver" or secondary circuit.

Since there is a direct current flowing in the primary of the induction coil and through the transmitter which is connected in series, the transmitter is able to vary the amount of the current in the same manner as previously described. The effect of this variable current in the primary is to produce an induced current in the secondary which permits the speaker to hear his own conversation as a sidetone. Sidetone is defined as that sound heard in the receiver caused by vibrations picked from the transmitter of the same telephone.

An incoming varying current from a transmitter at the distant point of the line passes through the primary of the induction coil, the transmitter, and back to its source. This current in turn induces a current into the secondary which is converted into sound energy by the receiver. Therefore, it is possible to transmit and receive signals using the circuit illustrated in Figure 2-20.

Transmitter, Receiver, and Ringer. Note that there are three distinct circuits in this telephone instead of four as there are in a local-battery telephone circuit. The transmitter or primary circuit includes the primary of the induction coil and the transmitter and is one complete circuit. The second circuit consists of the secondary of the induction coil and the receiver. The third circuit is composed of the ringer and its series capacitor.

Hookswitch. Signaling the operator in common-battery telephone operation is done by completing the DC path through the line and transmitter. In the circuit illustrated in Figure 2-21, the path of the direct current is always completed through the primary of the induction coil and the transmitter. In order to open this path when the telephone is not in use, it is necessary to insert a hook-

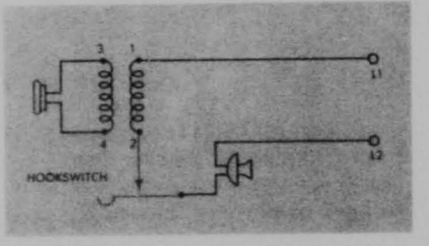


Figure 2-21 Hookswitch in Telephone Circuit

switch in the circuit. The closing of the hookswitch causes a signal to appear on the switchboard and indicates to the operator that a call is to be placed. So far as signaling the operator is concerned, it is not necessary to open the receiver circuit with hookswitch contacts so long as the receiver remains connected to a separate circuit. Figure 2-21 illustrates the circuit with the hookswitch added.

Ringer Circuit. There is but one circuit which remains to be added to complete the telephone for operational purposes and that is the ringer. This circuit enables the switch-

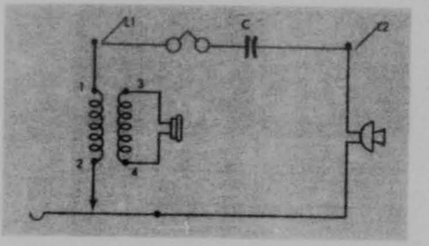


Figure 2-22 Capacitor & Ringer in Telephone Circuit

board operator to signal the subscriber that there is a call for him. The ringer must be across the line but must not allow the direct current to pass through it. To accomplish this a capacitor is connected in series with the ringer; this permits the ringing current to pass but blocks the passage of the direct current. Figure 2-22 illustrates the circuit with the ringing circuit added. This is a complete basic common-battery telephone circuit.

Common-Battery Telephone, TP-6. Common-battery antisidetone telephones such as Telephone TP-6 shown in cutaway form in Figure 2-5 are used on loops to common-battery switchboards, and the direct current for the microphone (transmitter) is obtained over the loop. The transmitting efficiency of these telephones is therefore not as high when connected to a short loop. On very short loops the transmitting efficiency is about the same as that of a local-battery telephone.

The microphone and receiver used in the handset which is a part of the TP-6 are similar in their performance to those in Handset TS-9.

The transmitting loss of the common-battery antisidetone telephone for different loops, compared with that of the local-battery telephone, is given by the empirical formula: $L = \frac{R}{4E} - 4$ db, where L is the amount in db by which the transmitting loss of the local-battery set, "R" is the total circuit resistance, and "E" is the voltage of the common-battery supply.

The various elements of a typical loop which contribute to the total circuit resistance and consequently to the amount of direct current which flows through the circuit are shown in Figure 2-23.

Figure 2-24 shows approximate transmitting losses of common-battery telephone TP-6 compared with local-battery telephone EE-8-( ).

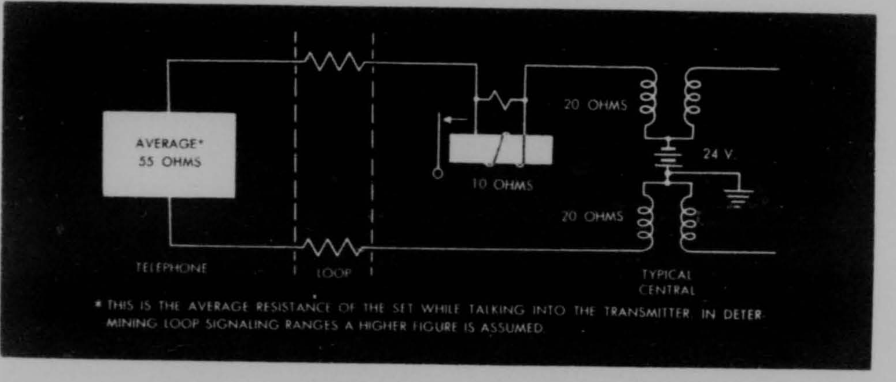


Figure 2-23 Typical Common Battery Loop Circuit

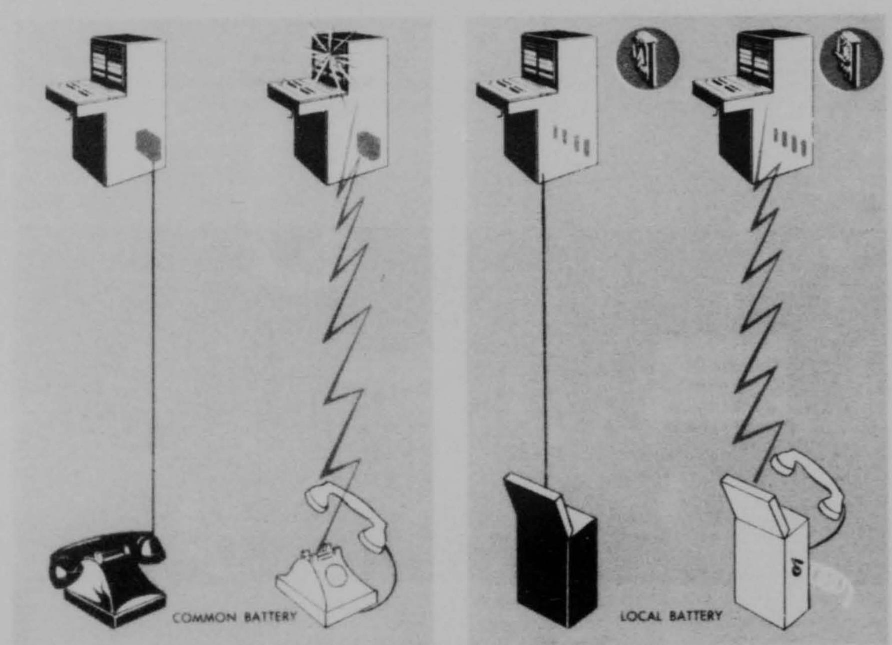
CONDUCTOR LOOP RESISTANCE — (OHMS)	TRANSMISSION LOSS (db)	
	24 VOLTS 50 OHMS IN CENTRAL OFFICE	48 VOLTS 400 OHMS IN CENTRAL OFFICE
0—200	*	*
200—400	0	0
400—600	2	1
600—800	4	2
800—1000	7	3

* FOR THESE SHORT LOOPS THE COMMON BATTERY TELEPHONE IS SLIGHTLY BETTER THAN THE LOCAL BATTERY TELEPHONE.

Figure 2-24 Comparison of Common Battery & Local Battery Transmission Losses

Common-Battery Switchboards

A common-battery switchboard is distinguished, principally, by its storage battery which is common to all of the battery supply and automatic signaling circuits in the switchboard. Battery supply for telephones on the loops is obtained from the cord circuits except in the cordless switchboard where it is obtained from the switchboard



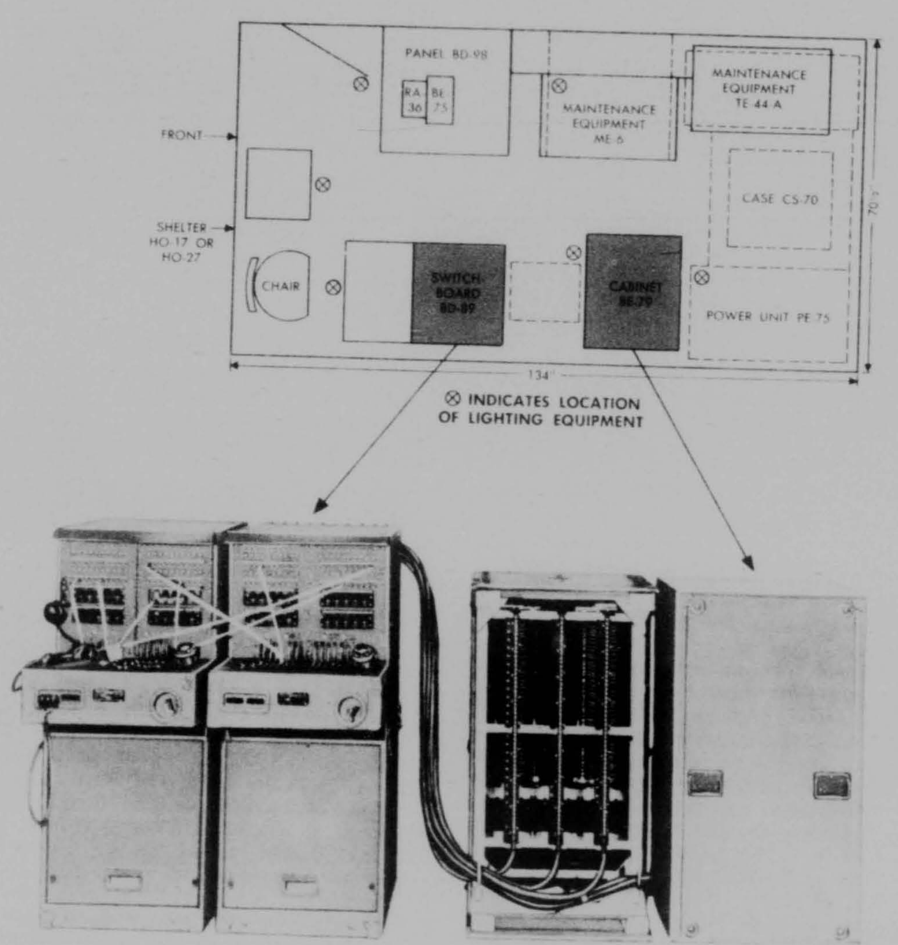


Figure 2-25 Telephone Central Office Set TC-2 Installed

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connecting paths. Other battery supply circuits are provided for the operators' telephones. Automatic signaling circuits are associated with the lines and cord lamp signals which are controlled from the switchhooks of the telephones on the loops. Similar signals are controlled from ringing on the trunks. These features contribute to high operating efficiency and are particularly desirable in large centrals.

Comparison of Common Battery Switchboards With Magneto Switchboards. The advantages of common battery switchboards in comparison with magneto switchboards are principally as follows:

a) Automatic signaling in response to the movements of the hookswitches at the telephones provides fast and reliable signals with almost no conscious effort by the telephone users. This reduces the work of the switchboard operators by eliminating, to a great extent, the need for monitoring to avoid excessive holding of trunks after conversations are finished.

b) A single storage battery for the switchboard and associated telephones is more desirable than dry batteries.

c) A common-battery telephone is lighter than a magneto telephone because it does not contain a hand generator or dry batteries.

The disadvantages of common-battery switchboards are in the working limits for signaling on the common-battery loops. These limits are based on the operating capabilities of the switchboard and require that the insulation resistances of these loops be maintained at more than 10,000 ohms. The insulation resistances on magneto loops can be as low as 1,000 ohms. The higher insulation resistances require greater care in the construction and more labor in the maintenance of the outside plant. The permissible conductor resistances of common battery loops are from 50 ohms to 1,000 ohms depending on the particular switchboard, whereas magneto loops generally can have 2,000 or 3,000 ohms, provided that voice transmission considerations permit.

On long loops, transmission is poorer with common battery telephones than with local battery telephones.

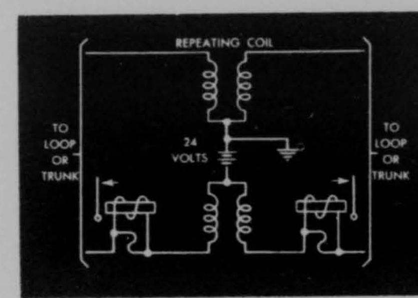

Figure 2-26 Repeating Coil 24 Volt Battery Supply Circuit

Battery Supply Circuits. The battery supply circuits in the cord circuits of some switchboards such as the Western Electric Company No. 11 Switchboard are of the **repeating coil type** with a 24-volt battery, as illustrated in Figure 2-26. In this circuit, the battery is connected in series with the windings of the repeating coil and the voice currents follow the same path as the battery supply currents through the battery. Although the voice currents from many different circuits pass through the same battery, these currents do not produce cross talk because the impedance of the battery is very low (less than 0.1 ohm), — provided that the leads to the battery are properly arranged.

Battery supply circuits of the **bridged impedance type** are arranged with the battery connected in series with retardation coils or relays which are bridged across the voice channels in the cord circuits. A battery supply circuit with a single bridged impedance is illustrated in Figure 2-27a. A similar circuit with two bridged impedances is illustrated in Figure 2-27b. The DC resistance of each of the inductors is small enough to permit the flow of an adequate amount of battery supply current for the telephone. However, their impedance to voice-frequency currents is high enough to avoid excessive transmission loss. In cord circuits such as those of Switchboard BD-110-( ), two bridged impedances are provided, one for the front cord and the other for the back cord; capacitors are connected in series with the voice channels between the bridged impedances (Fig. 2-27). In the double bridged impedance

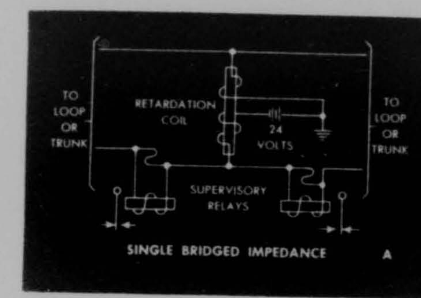

Figure 2-27a Single & Double Bridged Impedance

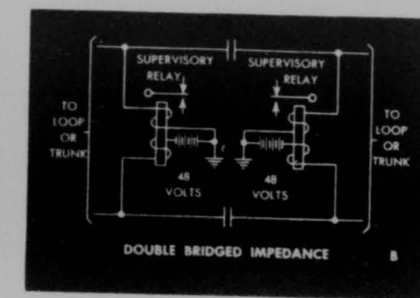

Figure 2-27b Battery Supply Circuits

type of battery supply circuit, each loop connects to a separate relay while in the single bridged impedance circuit both loops connect to a single retardation coil. The single bridged impedance type of circuit is suitable only where most of the loops are relatively short because the shunting effect of a short loop on the same cord circuit.

Signaling on Common-Battery Loops. When a call to a cord switchboard is originated at a common-battery telephone, direct current flows from the switchboard line circuit. This causes the lighting of all line lamps connected to that line. When the call is answered by an operator, the flow of current from the line circuit is cut off by the connection of a cord to a jack, but the battery supply current then flows over the loop from the cord circuit. Battery supply currents flow through the windings of relays, the contacts of which control the supervisory lamps or signals. Telephones are signaled from the switchboard with ringing current applied to the loop by the operation of a ringing key in the cord circuit.

Common Battery Cord Circuits. The cord circuits in common battery switchboards contain the battery supply circuits described in the paragraph above; they also contain relays and lamps for producing supervisory signals; and they include keys for ringing on loops and trunks, and for connecting the circuits to the operator's telephones. The different types of common battery cord circuits are broadly classified as local cords, universal cords, and PBX cords. All cords in a single type of switchboard are of the same type.

5. AUTOMATIC TELEPHONY

General

An outstanding disadvantage of the manually operated switchboard system is the fact that the boards require operators, and time

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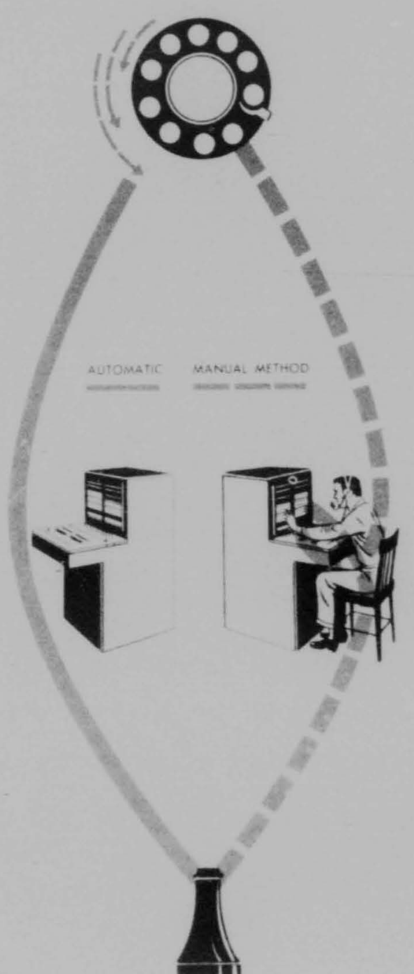

is consumed in making connections through switchboards. From the earliest days of telephony, the inventors have devised various schemes for eliminating this disadvantage.

While the bulk of our tactical equipment is composed of manual types, this is not true in the case of the telephone systems of large installations such as peacetime permanent stations or wartime high level headquarters. Today, the communicator must be aware of the problems and principles involved in automatic telephony.

Basically, automatic telephone systems are those in which the switching operation is automatic. Such systems make it possible for telephone stations to connect with other desired stations through a process which amounts to remote control.

Basic Automatic Systems

There are generally three types of automatic systems. These are as follows:

The step-by-step system incorporating driving magnets in each switch. This switch is put into operation by the calling party and through a series of short steps makes connections with the called party's line.

The power-driven system in which the switches are connected through clutching to driving motors. The calling party applies control to the switch which makes the necessary connection.

The all-relay system in which the calling party selects the called party through a system of relays without any form of power switch arrangement. Each of these systems has, as we have seen, different methods of selecting the called party. The device that initiates these is a keying device known commonly as the "dial". Automatic systems are normally referred to as "dial" systems.

The system most commonly used on Air Force bases is the step-by-step system. Since it was the invention of Almon B. Strowger in 1889, it is called the Strowger step-by-step system. Such a system requires a dial at the telephone, relays and switches at the switching central, and the normal ringing equipment at the called telephone.

The Dial System

The dial system sequence and process is as follows:

Dial: serves to transmit the coded impulses. This corresponds to the caller asking the switchboard operator for the called number.

Line Relays: serve to supply power to the appropriate switches. These correspond to

similar relays in manual boards which activate lights on the board.

Line Finder: is a switch mechanism connected to the telephone circuit. It has the function of seeking a calling line from a large group of lines. There are in most military boards about 20 such switches for each 100 numbers. These correspond to the signal lamps and caller's jackstrip on the manual board.

Selectors: switch mechanisms similar to line finders in principle, but with the purpose of hunting and selecting groups. Thus, if a caller wants number 600, the selector finds an available channel on which number 600 may be reached. This corresponds to the operator picking up the proper plug and looking for the proper channel.

Connectors: switch mechanisms similar to the previous types. These serve to make the final connection to the called party. They correspond to the operation where the manual switchboard operator plugs the calling party into the called party's jack.

Additional relays: serve to introduce busy signals, ringing current, or any other special signal which should be placed in the circuit.

Military Automatic Systems

The automatic telephone system is not used in most echelons of Air Force units in the field. Other than for base-housed units, the dial telephone will not be found in lower echelon systems.

For purposes other than to acquaint the student with the fact that such systems are employed extensively at most Air Force installations, no further mention will be made of automatic telephony.

6. SOUND-POWERED TELEPHONES

Sound-powered telephones are used for point-to-point connections where the line loss is relatively low. They can also be used on switchboard connections where the performance of dry batteries in local-battery telephones is unsatisfactory. However, substandard transmission will be obtained on switchboard connections unless the loop and trunk losses are very low.

Compared with the local battery telephone EE-8-( ), the sound-powered Telephone TS-3 which employs Handset TS-10, is about 25 db lower in transmitting efficiency.

Handset TS-10 contains a resonant magnetic receiver in which the diaphragm is undamped and unclamped at the edge and the armature drives the diaphragm through a mechanical coupling. In this type of receiver, greater efficiency is obtained over the conventional type of magnetic receiver, where there is no mechanical coupling between the diaphragm and the pole pieces, without introducing an excessive amount of frequency distortion. The receiving efficiency of Telephone TP-3 is about 10 db more than that of Telephone EE-8-( ). This 10 db improvement in receiving efficiency is ineffective where the line noise is high.

The sound-powered telephone is suitable for use on point-to-point lines which have a maximum loss of about 15 db. If the line noise is excessive, this limit may drop to 5 db. If it is used in the transmission plan referred to previously, transmission will be below standard, even where the loops are very short, since the trunk line loss may exceed 15 db.

Because of the relatively high impedance of the sound-powered handset, the maximum efficiency is obtained when no induction coil is employed and the instrument is connected directly to the telephone circuit. On some short point-to-point circuits where signaling is not required, the sound-powered Handsets TS-10 may be used without other parts of the telephone.

SECTION 3 - TELETYPEWRITER SYSTEMS

1. GENERAL

Transmission of messages by means of the teletypewriter has become an integral part of the USAF communications system. Teletypewriter equipment designed for the United States Air Force is capable of operating either over wire, radio, or integrated wire-radio systems. The common types of teletypewriter equipment in use today for military communication are designed for flexibility, mobility, and ease of operation. Teletypewriter equipment may be used over a transmission facility to give direct circuit, traffic is restricted to messages between two terminals. However, in the case of a system, its flexibility permits messages to be transmitted to any destination within the system. As a system, it is as flexible as the telephone. The system is widely used in both military and civilian communications networks. Since teletypewriter equipment is portable, a variety of installations is possible. It may be operated as a mobile station when mounted in a vehicle; it may be used in any tactical situation with combat troops. Although teletypewriter equipment requires operators with some degree of skill, the operation is comparatively easy since the keyboard is similar to that of a standard typewriter.

When compared with the telephone, teletypewriter service may be considered a more efficient and expeditious agency for handling large volumes of traffic without an increase of outside plant. It has the additional advantages of providing greater transmission range over similar facilities, printed record of the messages transmitted, and more efficient use of communications because of the volume of traffic which may be handled. The teletypewriter may be used for interchanging information in a conversational manner similar to the telephone.

The United States Air Force has many uses for the teletypewriter service. One of the most extensive is the provision of these facilities for the collection and dissemination of weather data. A variety of nets may be established to transmit weather information from a central organization to the smallest unit requiring this service. A special teletypewriter is employed in the weather service. The handling of administrative and operational traffic over teletypewriter systems greatly relieves other means of communication. During combat operations, teletypewriter facilities are excellent for transmitting lengthy field orders.

Generally, the equipment requirements for teletypewriter networks are dependent upon two factors: type of circuit facilities available, and number and size of units to be served. A system is made up of numerous components including stations with their individual extensions, main transmission circuits, terminal and repeating equipment, retransmitting equipment, switchboards, and branch circuits extending to outlying localities.

The United States Air Force has available for its use a specially adapted teletypewriter used in cryptographic systems. These machines are employed extensively to transmit classified material.

2. PRINCIPLES OF OPERATION

Teletypewriter Code

No attempt will be made to discuss in detail the design features or operating methods of each teletypewriter, but consideration will be given to some of the general features applicable to all of them. Teletypewriter operation differs essentially from manual telegraph operation only in the substitution of sending and receiving machines for keys and sounders. The signaling code used is not the Morse code of manual operation but a special one in which each letter or signal is made up of five units or elements of equal length. These units or elements are known as **marking** or **spacing impulses.** Figure 2-28 illustrates this teletypewriter code.

Marking impulses or signals are those impulses which operate the selector magnets in the receiving printer. Spacing impulses or signals are those impulses which do not operate the selector magnets in the receiving printer. The marking and spacing impulses are of the same length.

Two more impulses are necessary, and being common to all code groups, complete the code group representing any letter, figure, character, or **stunt,** making the total number of impulses seven. One of these is a spacing impulse and is the first impulse sent. Its function is to set the receiving machine in motion and in readiness to receive the remainder of the code group. This impulse is the same length as the code impulses which follow and is called the start impulse. The other impulse is a marking impulse and is always the last impulse of each code group. This impulse is known as the "stop" impulse and is 1.42 times as long as any of the other impulses. Its function is to return the re-

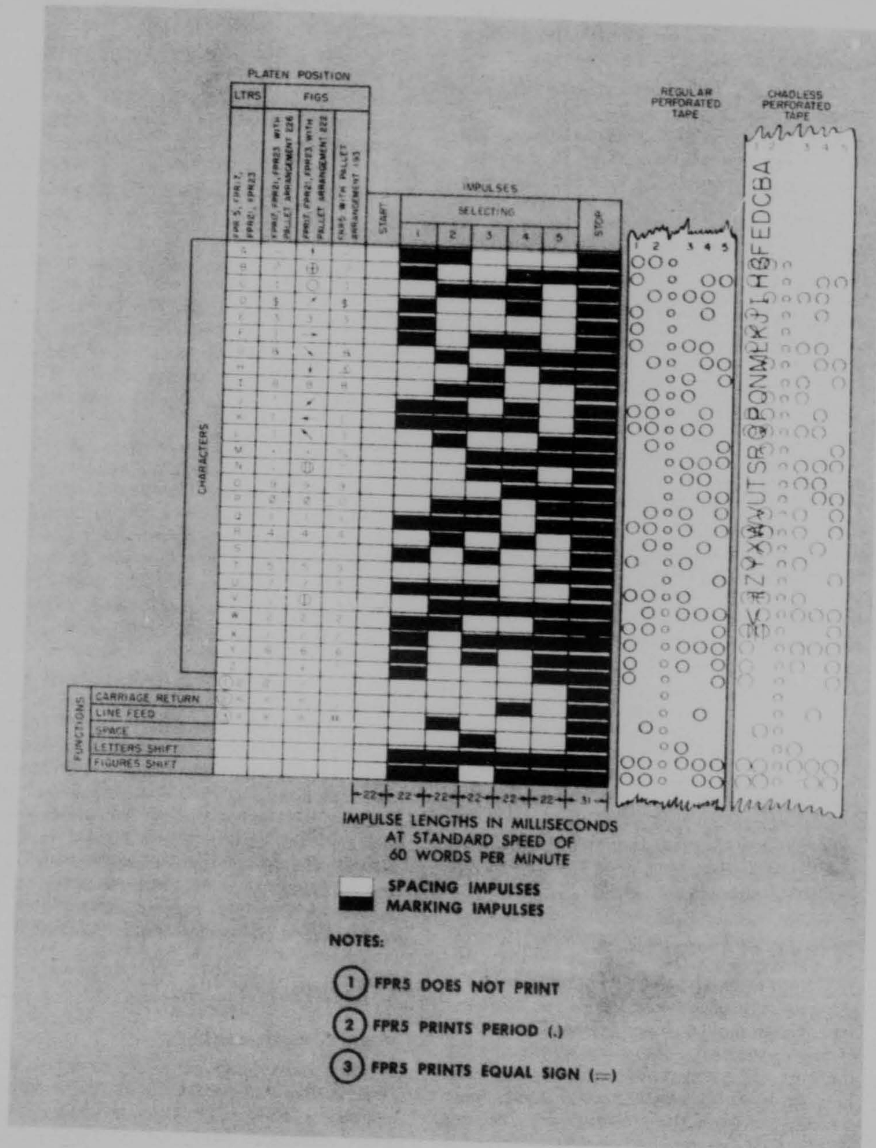

Figure 2-28 Teletypewriter Code Chart

ceiving printer to a position of readiness for the next starting impulse. This pulse maintains the synchronism between the sending machine and the receiving machine.

The teletypewriter code provides for the letters of the alphabet, the numerals, and several miscellaneous symbols in common use or specially desired, as well as for the special operations or stunts that the machines must perform, such as line feed, carriage return, miscellaneous switching and signaling features. The provisions are made by using the thirty-two combinations that the five-impulse code permits and a **letters shift-figures shift** feature. The machine must be so designed that when a certain letter key is operated at the sending machine, the marking and spacing signals corresponding to the code for that particular letter is sent out on the line, and when this signal combination arrives at the receiving machine, the corresponding type bar is selected and operated to print the letter. The code is known as the five-unit permutation code and is sometimes called the five-impulse start-stop code. A six-unit code, which contains sixty-four different signals, is used when it is necessary to transmit capitals, small letters, numerals, and punctuation, or other marks or symbols.

Speed of Operation

The standard military teletypewriter is designed to operate at a maximum speed of sixty words per minute. This high signaling speed requires not only that the transmitting and receiving machines be sturdy and dependable, but also that the transmission lines and teletype repeating apparatus be of the highest grade.

Systems of Transmission

There are two important systems of transmission in teletypewriter systems: the **neutral system** and the **polar system**. DC neutral circuits operate on the basis of current for marking and no current for spacing. A metallic pair or a wire with ground return may be used between the sending and receiving points. Simple open-and-closed operation is sometimes used between the teletypewriters connected directly to the line without relays. In such cases, operation between teletypewriters is limited to distances of approximately a mile when field wire (W-110) is used. This limitation is imposed primarily by signal distortion resulting from varying weather conditions. This distortion cannot be compensated for readily by adjustment of the teletypewriter mechanism. However, this form of signal distortion can be overcome to a certain extent by interposing an adjustable receiving relay between the line and the teletypewriter.

In DC polar circuits, approximately equal values of positive and negative voltages are applied alternately to the line at the transmitting end. At the receiving end, the polar relay responds to the direction of the current rather than to its magnitude. A one-way polar circuit generally uses one metallic conductor with a ground return, but two metallic conductors may be used. A 2-path polar circuit consists of two one-way polar circuits and is suitable for duplex operation provided the local circuits are so arranged. Over wire circuits, teletypewriter operation which is limited to one direction at a time is known as a single or half-duplex operation. A break feature is provided to enable the receiving station to break or stop the transmitting station.

In any teletype circuit (wire or radio) in which independent transmission paths are provided for the two directions of transmission, it is possible to transmit messages in both directions simultaneously. This is known as duplex operation, and is sometimes called full-duplex operation. This method involves certain inconveniences from an operating standpoint, but allows moving approximately twice as much traffic as the half-duplex method. Carrier teletypewriter service is partially suited to the duplex method.

3. EQUIPMENT

Major Components

Teletypewriter equipment is classified in a general way as "tactical" and "fixed plant" equipment. Electrically these two classes are interchangeable. However, tactical equipment is characterized by its portability and ease of installation. Fixed plant equipment

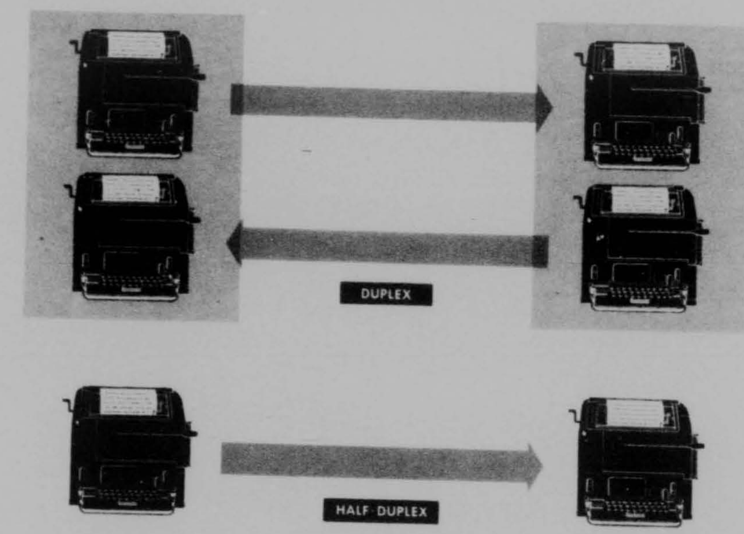

Figure 2-29 Duplex & Half Duplex Teletypewriter Operation

is not readily moved from one location to another, considerably more time is required for installation, and greater protection from the weather must be provided.

Teletypewriters which are commonly used in the Air Force have two types of keyboard. These are the communication keyboard and the weather keyboard. Columns 1 and 4 in Figure 2-28 illustrate the characters found on the communication teletypewriter keyboard, while columns 1 and 3 are those of the weather keyboard. It is noted that they are the same in the lower case but differ in some of the upper case characters. The communication arrangement has punctuation marks where the weather arrangement has symbols such as arrows to indicate wind direction, for the transmission of weather data.

Two basic forms of teletypewriter recording are used. One of these forms of recording is the printed page. The other is the perforated tape with or without printing. Equipment which records the messages as typed characters and in perforations in the tape is called a "typing reperforator". The basic forms of transmission are: manual sending from a keyboard or automatic sending by means of a perforated tape from a transmitter-distributor.

Teletypewriter equipment for tactical use is manufactured so that connections may be made rapidly with cords and plugs and without the use of tools. The equipment is portable and is packed in wooden chests. Tactical teletypewriters require more protection than that afforded by the carrying cases. The teletypewriter TG-7 ( ) is a portable page-printing machine designed for two-way communication. It is the major component of Teletypewriter Set EE-97 ( ). When assembled for use, the chest provides a convenient operating table and seat for the operator. This machine operates on 115-volt direct, or alternating, current. It is arranged so that 25, 40, or 50, 60 cycle alternating current may be employed. For printing messages, the single page or multiple copy may be used. The teletypewriter may be used over wire circuits, radio circuits, or through a teletypewriter switchboard in a manner similar to the telephone.

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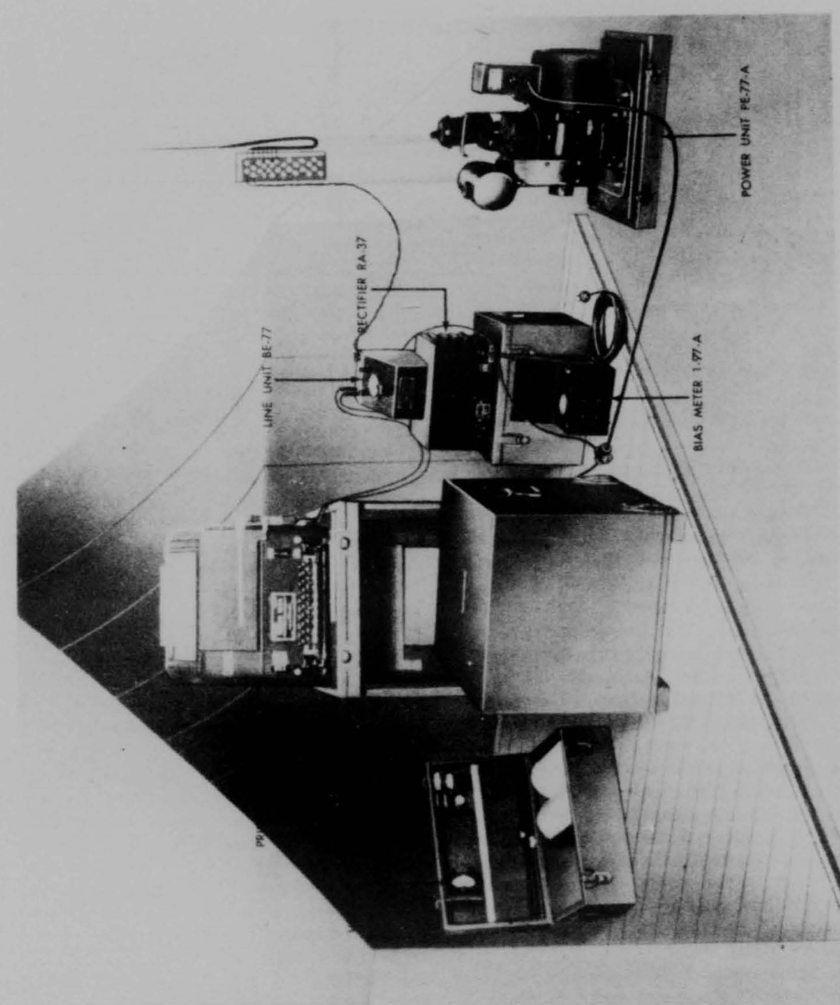

Figure 2-30 Teletypewriter Set EE-97

Automatic tape transmissions are accomplished by the use of reperforator transmitter and distributor sets. There are several types used by United States Air Force units for the transmission of both weather and communication messages.

The TG-26 and the TG-27 Reperforator Transmitting Sets each consist of a sending-receiving transmitter-distributor, connection box and chest. The TG-26 is equipped with the communication characters while the TG-27 is designed for the transmission of weather data.

The typing reperforator may be used to transmit directly to the line and to monitor the message by printing on, and perforating, a tape. When tape transmission only is desired, the typing reperforator may be operated locally and the tape thus perforated may be used for operating the transmitter-distributor. The typing reperforator may also be connected to the circuit to receive signals from a distant point to prepare a tape for subsequent transmission. The following are some of the most common operating combinations of TG-26 and associated TG-26 sets or TG-27 and TG-37 sets which may be connected in the circuit:

To send manually from the typing reperforator into a local loop to print and reperforate a tape. Perform the same operation and simultaneously print a page copy.

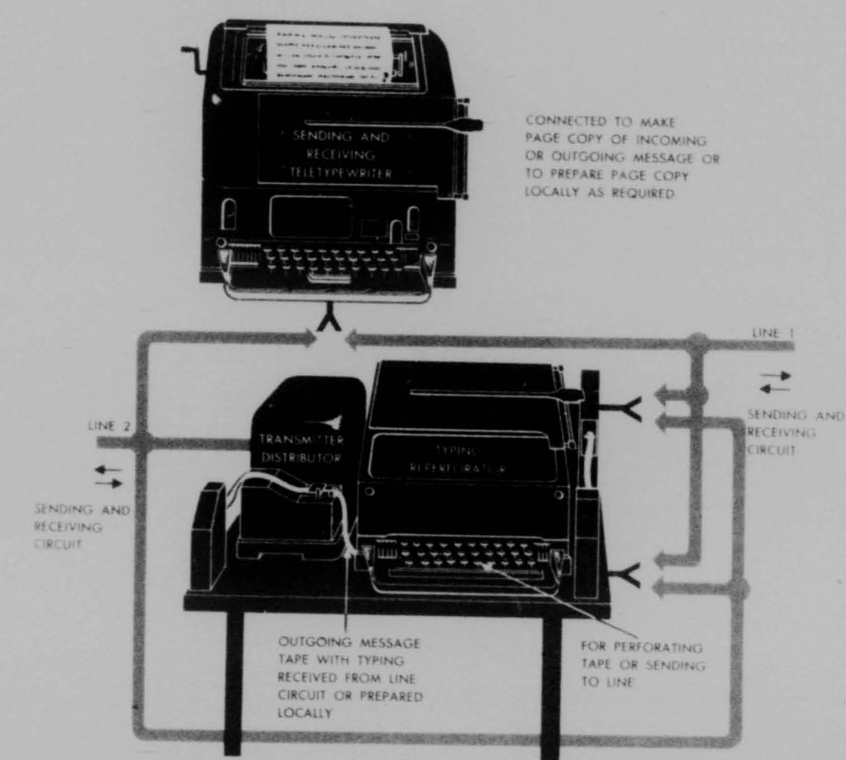

Figure 2-31 Reperforator Transmitter TG-26

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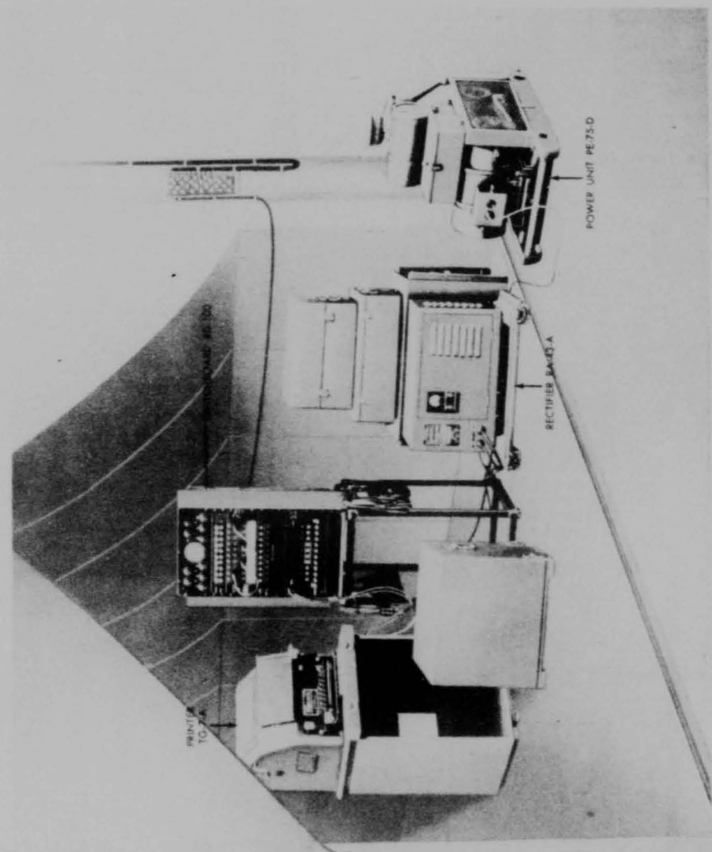

Figure 2-32 Telegraph Central Office Set TC-3

To send into a local loop from the transmitter distributor, with tape previously perforated, to print page copy.

To send from the typing reperforator into a signal line and at the same time print and perforate a tape. Perform the same operation and print a page copy simultaneously.

To receive line signals and print and perforate a tape and simultaneously print a page copy. Operate the typing reperforator in a local loop or connect it to a line to receive printer signals. In either case, print and perforate a tape.

The typing reperforator and the transmitter-distributor are equipped with individual motor power switches.

The type of tape used with TG-26 is called "chadless." In this tape the perforations are partial in order to retain paper for the typed symbols. The perforations for a character are offset six spaces to the left of the printed character. Using the arrangement of perforator and transmitter-distributor permits the handling of a larger volume of traffic, since the tapes may be prepared locally and characters sent into the line automatically at the maximum line circuit signaling speed which may be 60 words a minute (3600 groups per hour) or higher.

The TG-25 is a motor-driven tape reperforating machine which receives electrically transmitted signals through the medium of a selecting and perforating mechanism into code combinations of holes in a paper tape. This tape may then be used for retransmitting these code combinations on other similar printing telegraph circuits, thus eliminating manual preparation of tape with a perforator at the relaying station. This type of machine provides an expeditious means for relaying messages and is commonly employed in Air Force installations.

The TC-3 is a complete, transportable teletypewriter exchange or central which can be easily and quickly installed at any headquarters requiring the use of a switching central with a capacity of ten teletypewriter lines or trunks. The line capacity can be increased by adding one Switchboard BD-100 for each additional ten lines. However, not more than three switchboards (capacity, 30 lines) can be used together as a single office because of power equipment limitations, length of patching cords and other factors. Each switchboard supplies the current and provides switching and repeating facilities for neutral operation of its ten teletypewriter lines or trunks. Provision is made for connecting any teletypewriter line to any other line or trunk or groups of instruments connected to the switchboard by means of patch cords. The operator's teletypewriter serves him in the same manner as the operator's telephone does with a telephone switchboard. He employs it to answer calls and to supervise connections.

Auxiliary Components

Certain additional equipment is required for completing the installation of the equipments previously discussed. These additional components include line units, rectifiers, repeaters, and power supplies.

The **Line Unit** BB-77 is a component of Teletypewriter Sets EE-97 and TC-16. The line unit is used to make connections between neutral-type telegraph circuits and teletypewriter station equipment, and to repeat signals which are transmitted from the line into the teletypewriter receiving mechanism. The line unit may be used for measuring voltage of the DC power source, and for measuring and adjusting the quality of the received signals. The unit in itself is small and compact.

On long tactical telegraph circuits it is often necessary to amplify or repeat telegraph signals so that the current received at the receiving machine will be strong enough to operate the receiving mechanism. This is accomplished by inserting **telegraph repeaters** in the circuit at periodic intervals. In tactical wire systems, telegraph repeaters TG-30 and TG-31 are used.

Telegraph Repeater TG-30 is a DC telegraph terminal-type repeater used for making connections from two-path polar or polarential line circuits to neutral type local circuits such as used in teletypewriters, Switchboard BD-100, Line Unit BE-77, and carrier telegraph terminals when long polarential circuits are employed. The TG-30 contains a built-in rectifier for operation on

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115 or 230 volts DC and also contains a built-in telegraph set. A 115-volt power receptacle provides an outlet for supplying power to operate a teletypewriter set.

The Telegraph Repeater TG-31 is a DC telegraph intermediate-type repeater for retransmitting signals from one polarential line section to another polarential line section (differential sending only). This type of repeater does not reform or retime signals. It will operate unattended on dry cell or storage batteries when a teletypewriter is not required at that point. It contains many of the same features that are contained in the TG-30.

Commercial-type repeaters are frequently used in rear areas where long distance circuits are employed. These repeaters are referred to as "package-type" and generally are installed in fixed plant installations.

When a source of AC power is available, a **rectifier** is normally required to convert the AC power to 115-volt direct current for the operation of the teletypewriter signal circuits and the line unit. Rectifiers RA-34 and RA-87 are the more common types furnished with the equipment. These units are small and readily installed.

A total maximum power input of about 200 watts is required for each teletypewriter set. All sets normally operate on stable sources of direct current or 50- to 60-cycle alternating current at 115 volts, although they will operate satisfactorily on stable voltages between 105 volts and 125 volts. Where rectifier RA-87 is available the sets may be operated on 50- to 60-cycle alternating current at stable voltages between 85 and 135 volts, and 179 and 270 volts.

The **power units** employed with this type of equipment for field operation are gasoline engine-driven generators which are capable of furnishing up to 250 watts at 115 volts DC. The unit is small and weighs about seventy-five pounds. It is provided with its own special packing case. Another unit is slightly larger and is capable of furnishing about 2.5 kilowatts of 120-volt AC power. This unit weighs approximately 320 pounds.

Whenever possible, commercial power or other local power facilities are used. This reduces the number of personnel required to operate the station, and also reduces the problem of maintenance since the gasoline engine requires a considerable amount of maintenance to keep it in the best operating condition. Furthermore, it conserves fuel, particularly when the station is operated on a twenty-four hour basis.

4. REQUIREMENTS AND PLANNING

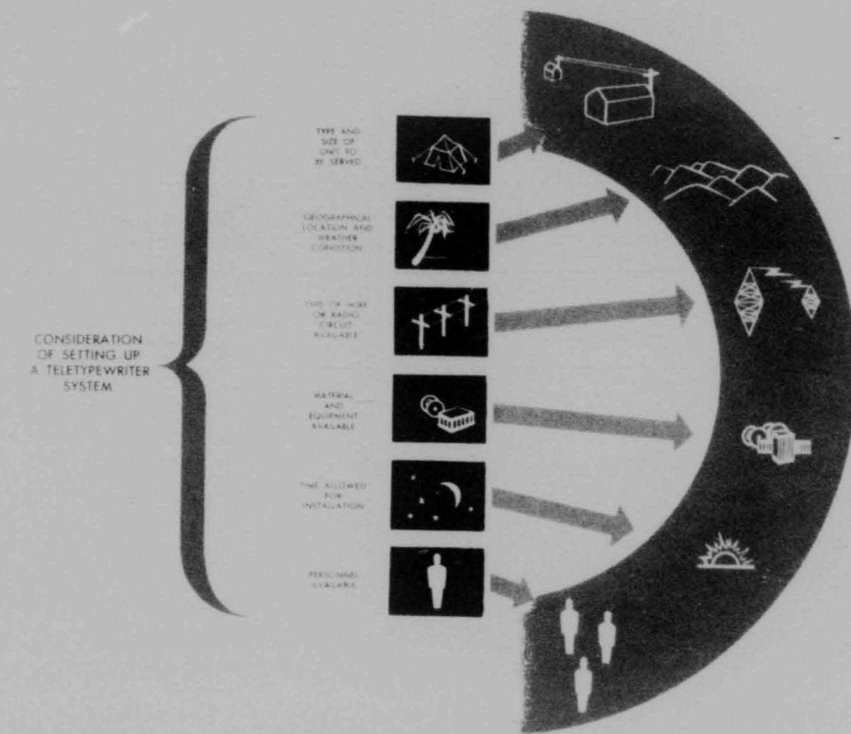
For planning teletypewriter systems and teletypewriter equipment installations, many factors must be considered in order to insure efficient and expeditious service. Advantage of telephone circuits should be taken as often as possible by superimposing telegraph circuits on them. This practice tends to effect economies, both in the amount of material used, and in the number of operating personnel required.

Whether teletypewriter equipments are used on direct (point-to-point) circuits or in a teletypewriter system, the following factors are important.

a) Type and size of unit to be served.
b) Geographical location and weather conditions.
c) Type of wire or radio circuits available.
d) Material and equipment available.
e) Time allowed for installation.
f) Personnel available.
g) Tactical situation.

Teletypewriter systems should be planned to give the greatest flexibility possible, in order that all units of an Air Force organization may communicate with each other directly by switching, or through a relay station. Planning of a teletypewriter system also includes the proper coordination with other staff sections of an organization. By doing so, implementation of plans is facilitated and quicker service insured. It readily may be seen that teletypewriter service greatly expedites the activities of an air force organization. Because of the flexibility of a teletypewriter system, the ease of operation and installation of the equipment, great volumes of traffic can be handled quickly and efficiently.

Teletypewriter equipment designed for field use is made to employ the same facilities provided for telephone systems or may be installed as a separate system. The use of



teletypewriter facilities greatly relieves the burden on telephone circuits and at the same time increases the traffic handling capacity of the communications system.

Present research and development in teletypewriter equipment and facilities will broaden the field for the use of this equipment both on the ground and for air-to-ground communication.

SECTION 4 - TRANSMISSION LINES

1. GENERAL

This section includes descriptions of the various common types of transmission lines, a discussion of the nature of these lines and of simple circuits.

The section will serve a dual purpose: to introduce a subject not discussed elsewhere, and to serve as an introduction to the following section on carrier telephony. The student must be acquainted with the capabilities and limitations of transmission lines in order to understand the principles of carrier operation.

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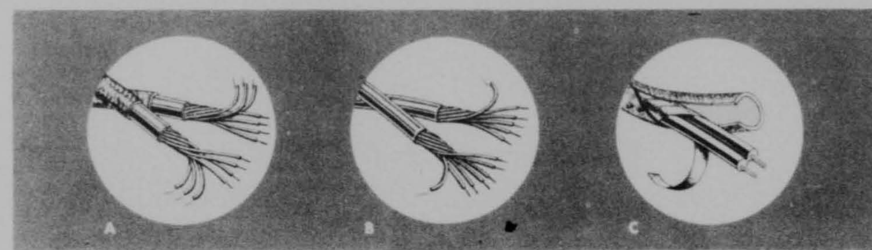
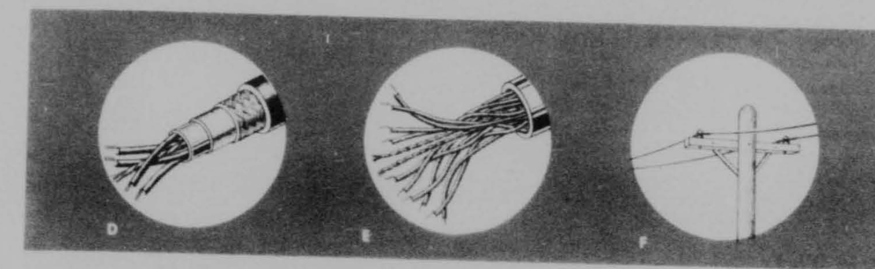


	W-110-B	W-130-A	W-143
NOMENCLATURE	Wire W-110-B	Wire W-130-A	Wire W-143
DESCRIPTIONS	Field Wire	Assault Wire	Long Range Tactical Field Wire
PHYSICAL PROPERTIES	7 Strands (4 steel, 3 copper) Cotton Braid Insulation Rubber Insulation Weight—120 lbs. per mile	7 Strands (6 steel, 1 copper) Rubber Insulation Weight—34 lbs. per mile	Parallel Pair, Stranded Soft Copper Rubber Insulation on Each Conductor Paper Shielded Overall Cotton Braid Weight—300 lbs. per mile
ELECTRICAL CHARACTERISTICS	D-C Resistance (ohms per loop mile): 176 Non-repeatered Range 20-db net loss: 11 mi.	D-C Resistance (ohms per loop mile): 625 Non-repeatered Range 20-db net loss: 5-7 mi.	D-C Resistance (ohms per loop mile): 35 Non-repeatered Range 20-db net loss: 27 mi.
MILITARY USAGE	Aerial, on Ground or Surface Installation for Loops and Short Non-repeatered, Non-loaded Circuits Range can be Extended with Loading Coils or Repeaters	Same as W-110-B (less efficient)	Tactical Usage Range may be Extended to 60 mi. if Loaded

Figure 2-33a Common Types of Transmission Lines



	CC-358	WC-534	W-080
NOMENCLATURE	Cable Assembly CC-358	Cable WC-534 and Cable Assembly CC-345 Cable WC-535 Cable Assembly CC-355A	Wire W-080 40% Copper Steel
DESCRIPTIONS	Spiral Four Cable	5-Pair Cable (10 pr. cable is identical in construction with additional 5 pairs)	Open Wire
PHYSICAL PROPERTIES	2 Pairs Stranded Copper (one, light colored, one dark colored) Core Spacer Rubber Insulation Metalized Paper Paper Wrapper Steel Wire Braid Rubber Jacket Weight—540 lbs. per mile	5 (10)-Pair Solid Copper, Each Rubber Covered Jute String in Center Rubber Jacket Weight—600 lbs. per mile Weight—1200 lbs. per mile	Copper Steel 40% Conductivity Relative to Amount of Copper Weight—192 lbs. per mile
ELECTRICAL CHARACTERISTICS	D-C Resistance (ohms per loop mile): 77 (loaded) Non-repeatered Range 20-db net loss: 40 mi.	D-C Resistance (ohms per loop mile): 86 Non-repeatered Range 20-db net loss: 19 mi.	D-C Resistance (ohms per loop mile): 42.6 Non-repeatered Range 20-db net loss: 120 mi.
MILITARY USAGE	4-Channel Carrier Operation Up to 150 mile Range when placed aerially (¼ mi. lengths equipped with Loading Coils and Connectors)	Short Loops where a number of Circuits are required. (Provided with Connectors for rapid installation)	Long Distance Use and Carrier Operation up to 32,000 Cycles

Figure 2-33b Common Types of Transmission Lines

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2. TYPES OF TRANSMISSION LINES

There are many types of transmission lines employed for military purposes. Many of these are listed in Figure 2-33. The most commonly used types include field wire, rubber-covered cable, open-wire lines, and lead covered cable.

Field Wire

For temporary construction over short distances assault or field wire (Figure 2-33) may be employed. The range with which satisfactory conversation may be had over these types of wire may be extended by the use of loading coils and repeaters which will be described in succeeding paragraphs. Assault and field wire are intended for use under combat conditions and therefore must be able to absorb a great deal of punishment. The wire is constructed of both copper and steel strands. The copper strands are intended for the transmission of the currents while the main function of the steel strands is to give mechanical strength. However, both components lend to the mechanical strength and to the conductivity of the wire.

Field Cables

Field cables are rubber-covered, varying in size from two to ten pairs. The two pair cable is a spiral-four quad primarily used for 4-channel carrier operation over intermediate distances (up to 150 miles when aerial construction is used). However, experience has proved that greater distances may be obtained when this cable is properly constructed, whether aerially or underground. Figure 2-33 illustrates the construction of spiral-four cable. The cable is constructed with connectors having built-in loading coils, so that induction is automatically added as length of cable are joined.

The 5 and 10-pair cables are used mainly for short loops where a number of circuits are required. These cables are also provided with connectors which can be plugged together for rapid construction of the line. Figure 2-34 illustrates the construction of a five-pair rubber-covered cable.

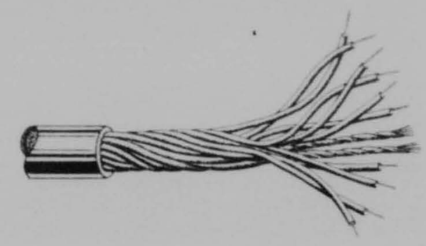


Figure 2-34 Five-Pair Cable Construction

Open-Wire Lines

Open-wire lines have relatively low losses at voice and carrier frequencies and can be used to provide circuits with satisfactory transmission characteristics for long lines within a theater of operations, although the use of repeaters at regular intervals is standard practice.

A type of open-wire construction has been developed for military use which combines the features or economy of shipping, space, weight of material, and good transmission characteristics which permit the operation of carrier systems up to 32,000 cycles per second. Such lines have transpositions designed for a maximum of two crossarms with four pairs per crossarm. Open-wire lines will usually employ 080 or 104 copper-steel for new construction and repair.

Commercial type of open-wire construction (ten-pin crossarms) is commonly used in a theater of operations, especially where permanent, long distance service is required.

Lead-Covered Cables

When the situation is stable enough to permit their use, lead-covered cables are employed to obtain comparatively large numbers of voice frequency circuits. Usually these circuits are built to include loading and repeaters. By burying the cable, a stable transmission medium is afforded.

Lead-covered cables have paper-insulated conductors twisted as pairs or quads. The cables are manufactured in many sizes from 7 quads (14 pairs) to 150 quads or more. The quads may be of two types: multiple-twin and spiral-four or star quad. The multiple-twin quad consists of two twisted pairs twisted together to form a quad, the diagonally opposite wires being used as a pair. Wires in long distance cables of American manufacture are usually 19 or 16 gauge solid copper.

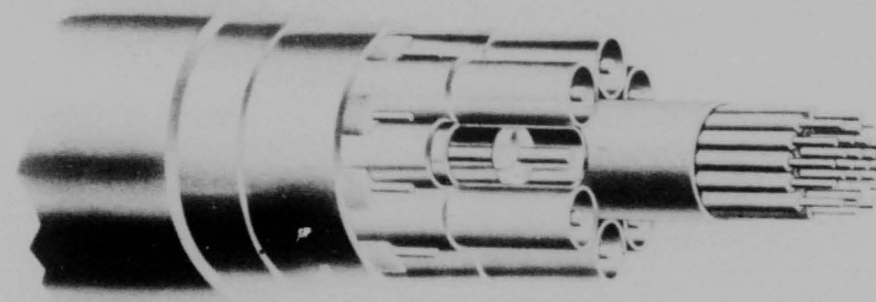


Figure 2-35 Coaxial Cable

Submarine Cables

Double-paper insulated submarine cables are suitable for depths of water up to 250 feet without danger of sheath collapse or excessive water penetration along the cable in case of sheath failure. Such cables may function satisfactorily for months or years in greater depths, but there is danger of a gradual sheath collapse or flattening due to excessive pressure, which may force the wires through the insulation. Special submarine cables are designed for much greater depths. Rubber-covered cables and wires may be employed as submarine cables, in emergencies. Care must be taken in this case to insure that the cable will not be subject to excessive abrasion or other mechanical damage and that all splices and connections are made water-tight.

Coaxial Cable

Coaxial cable in its basic form consists of a center conductor mounted inside of and coaxial with an outer metallic tubing or metallic braid conductor and separated from it by spaced insulators or solid insulation. Coaxial cable is an excellent means for transmitting high frequencies since its characteristic impedance is extremely low (usually around 75 ohms). It is used commercially for long lines: telephony, telegraphy, and more recently, for television. Figure 2-35 shows several coaxial cables within a common sheath and separated from each other by insulating materials. Many individually insulater copper wire conductors are often included to provide for more transmission paths and to help fill up space which otherwise might be wasted with unnecessary amounts of insulation material.

3. NATURE OF TRANSMISSION LINES

Electrical Characteristics

Metallic lines are affected by electrical and mechanical factors which tend to disturb the transmission of messages over the line. There are four fundamental characteristics which exist in a line when currents are passed through them. These are: resistance, capacitance, inductance, and leakage.

Resistance. Every conductor offers resistance to the flow of electricity. The resistance

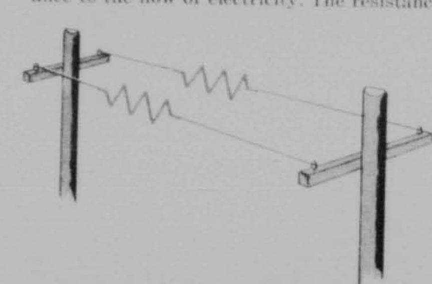


Figure 2-36 Every Conductor Offers Resistance

of a few feet may be of no particular consequence, but the resistance of several miles of wire is great enough to be considered. In telephone practice, the resistance of a line is stated in terms of ohms per loop mile. A loop mile includes the resistance of both conductors of a pair or twice the resistance of one conductor of the pair. One of the most widely used sizes of wire has a resistance of 10 ohms per loop mile. Therefore, if a line is many miles long the resistance of the line is large and must be taken into consideration.

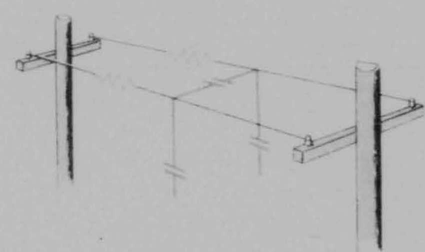


Figure 2-37 Any Two Conductors Separated by a Dielectric Form a Capacitor

Capacitance. Any two conductors separated by a dielectric form a capacitor. Two conductors when separated by air or any other dielectric material, such as paper or mica, serve as the plates of a capacitor to produce capacitance between the wires.

In like manner, the two wires serve as one place of a capacitor and the ground will serve as the other, thus, providing capacitance to ground. As the area of the plates of a capacitor increase and as the distance between the plates decrease, the capacitance increases as the length of the line increases.

Inductance. Every conductor offers some inductance to a varying current. Because of the varying currents associated with the transmission of intelligence over a telephone, there are lines of magnetic force both in the conductor and in the immediate adjacent space. Since the current which produces these lines is varying, the associated magnetic field also varies. This magnetic field will cause other currents to be set up in the wire itself. These are known as self-induced currents.

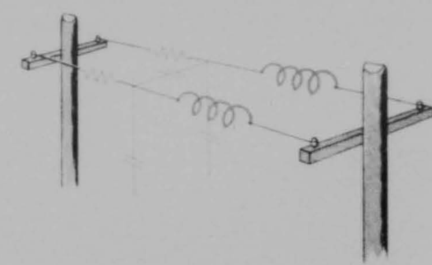
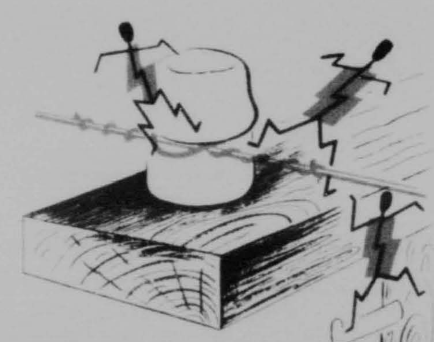


Figure 2-38 Every Conductor Offers Inductance When AC Passes Through It.

Also, if there are other wires which parallel the line carrying the current there will be currents induced in them, caused by the magnetic field encircling them. This is known as "mutual inductance." Wire lines other than telephone lines, carrying current, (such as power lines) adjacent to telephone lines, tend to set up magnetic fields and produce induced currents in the telephone lines. Normally, self-inductance of a line is small and the effect harmless whereas mutual inductance in a telephone line is the more harmful characteristic and must be given due consideration when designing a line.

Leakage. Since no insulator is perfect and although the insulation resistance between a pair of wires is very high, there is a certain amount of current dissipation between wires and ground. This loss of current is referred to as leakage. The amount of leakage depends



upon the insulation resistance, and varies with the weather conditions. Leakage increases in damp and wet weather.

Physical and Mechanical Characteristics

The fundamental characteristics of wire lines just discussed are further affected by the physical and mechanical characteristics of metallic lines. The physical properties, composition, and mechanical design of the conductor offer a variable resistance to the passage of electrical currents which depends upon the properties of the material selected for the conductor. Since the electrical properties of a line vary, it is logical to assume that the quality of transmission of messages will vary accordingly. While it is convenient to indicate that these electrical properties exist at definite points along the line, for the matter of computing the behavior of the line it must be remembered that they are distributed evenly throughout the line. In other words, each infinitesimal part of the line will have each of these characteristics.

Characteristic Impedance. If alternating current is passed through a telephone line which is infinitely long, the cumulative effect of the electrical characteristics discussed earlier would be so great that practically zero current would flow at the distant end of the line. Therefore, if the distant end of the line were open-circuited or short-circuited, the impedance of the line measured at the input end would be the same since there would be little or no current flow in the circuit. The line would have a definite impedance that would not change regardless of how the distant end was terminated. This impedance is called the "characteristic impedance" of the line. It can be expressed simply as the impedance of an infinitely long line, or the equivalent of an infinitely long line. The characteristic impedance depends upon the size of the conductors, the spacing between the conductors, the type of line construction, and the frequency of the transmitted current. Hence, the characteristic impedance of two different lines is not necessarily the same. Two identical lines, however, constructed in the same way will have the same value of characteristic impedance for a given frequency. Since the characteristic impedance varies with the different types of wire lines, the design of equipment is based on the characteristic impedance of the ideal transmission line. In the majority of cases, an open-wire line has a characteristic impedance of from 500-700 ohms. In cases where the line lacks the ideal impedance, equipment is added to the line so that it will approach the ideal condition.

Reflection Loss. Another phenomenon that occurs in all types of wave propagation is that of reflection. For example, when light strikes the surface of a clear body of water, some of it travels at slightly decreased velocity through the water to illuminate the bottom, while the remainder of the light is reflected from the mirrorlike surface of the water. An electrical wave behaves in a similar manner when the characteristics of the medium through which it is traveling changes. (See Figure 2-39.) Part of the energy travels on down the line while the remainder of it is reflected back toward the source. In wire communications, a reflection is more apt to occur at the junction of two different types of wire lines or at any point at which the characteristic impedance of the line makes a sudden change. The reflection of energy is

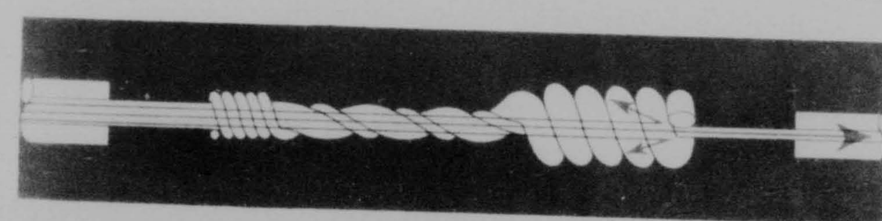


Figure 2-39 Reflection Loss

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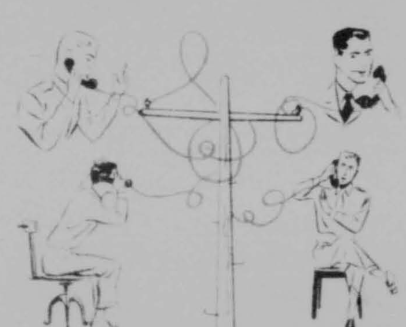
called the reflection loss. In order to reduce reflection losses, most telephone equipment is designed to have the approximate characteristic impedance of the ideal transmission line.

Attenuation and Frequency Distortion. Since all the power entering the transmission line at the input is not received at the output end, there is a definite loss that must be associated with the characteristics of the wire. In telephone and telegraph practice, this loss is called "attenuation." The attenuation of a line is not constant for all frequencies that the line is called upon to transmit. The higher the frequency the higher the attenuation. In other words for a given line, the attenuation is proportional to the frequency. Since the low frequencies are attenuated to a lesser degree than the high frequencies, distortion occurs. Low frequencies are transmitted better than the high frequencies and therefore are better understood. This distortion is known as "frequency distortion." It may be corrected by inserting loading coils or equalizers, or a combination of both, in the line. The function of these is to increase the transmission of the high frequencies.

Crosstalk. A common interference and characteristic of improperly designed and constructed telephone and telegraph systems is crosstalk. Crosstalk may be defined as intelligible sounds heard on one circuit as a result of speech transmission over another circuit. The three principal causes of crosstalk are: the **magnetic effect** between two circuits, the **capacitance effect,** and **resistance unbalance** in its own circuit. Crosstalk may



result from the leakage current between two circuits. Normally, with properly maintained circuits, the insulation is sufficient to make the crosstalk caused by leakage only a minor consideration. Crosstalk may be produced by magnetic effect; that is, by the magnetic field of one circuit cutting the wires of another circuit, and inducing a current in that circuit. Because of the greater separation of the wires in an open-wire line there is a greater difference in the voltages in each wire of the adjacent pair than will occur in adjacent pairs of a cable. The magnetic effect in an open-wire pair, therefore, is greater than in a cable pair.

Capacitance effect is caused by the difference in the capacity between the wires of two circuits. Since the capacitance increases as the separation of the two wires decreases, it is reasonable to expect that the capacitance effect will produce crosstalk in the circuits in cables. The difference of potential in one circuit causes a difference of potential in an adjoining circuit, producing crosstalk.

Resistance unbalance is caused by one wire of a pair having a greater resistance than the other wire. This difference of resistance may be the result of employing different gauges of wire, improper splices, poor connections, or faulty equipment. A line may be balanced by correcting the improper conditions that exist in the construction or by adding the proper amount of resistance to the other wire of the circuit in order to make the resistance of the wires equal. The adding of the resistance is to be avoided if possible since it increases the attenuation of the circuit.

Noise. Interference which produces an unintelligible sound heard over telephone circuits may be defined as "noise." Though crosstalk currents may appear as noise, the principal cause of noise is the induced currents from power lines. A special type of noise produced from a conglomeration of unintelligible speech sounds is known as "babble."

Babble occurs mostly in cable lines, where any crosstalk heard may be induced simultaneously from a number of other circuits as a result of the close grouping of the wires within the cable.

The disturbing effect of noise depends upon the intensity and frequency of the current producing the noise. Experiments have shown that the disturbing effects of noise are most pronounced at a frequency of 1100 cycles per second. Noise is not only irritating to the listener, but if the intensity is great enough, it may reduce the intelligibility of the conversation. It is important, therefore, that the noise level of the circuits be kept below a point that will not seriously interfere with telephone conversations.

Noise introduced by power lines may be largely eliminated by adequate separation of the lines. Normally a separation of the width of a road will prove a sufficient distance for the normal voltages employed in electrical distribution systems. However, for the high voltage transmission systems a greater separation will be required.

Transmission Losses and Gains

Since any line facility of the type described decreases the intensity of the voice currents as they pass through the transmission line, and the additional line and terminal equipment introduce additional losses, some method must be employed to make up these losses. The term "transmission losses" is employed to describe these losses. On short lines there may be no need to apply means for making up these losses since the conversation still may be readily understood. However, on longer lines the transmission losses may reach such proportions that it becomes necessary to make them up in order that intelligible speech may be reproduced. Telephone repeaters are employed in order to overcome these losses. The repeater is a vacuum tube device and may be adjusted to give the desired value of amplification or gain. Several repeaters may be employed if the circuit is long.

The transmission losses and gains are expressed in terms of a unit called the **decibel** (abbreviated as **db**). For wire communication, a signal level of one milliwatt (0.001 watt) has been adopted as the standard reference level. Zero db corresponds to one milliwatt of power. A positive (+) number of db indicates a power level greater than one milliwatt; while a negative (—) number of db indicates a power level less than one milliwatt.

A form of graph known as an **energy level diagram** is used in both the design and maintenance of long lines employing repeaters. These diagrams give a pictorial or graphic illustration of energy levels throughout a circuit. The signal levels expressed in db's are shown for both the transmission line and the associated terminal and intermediate equipment. Figure 2-40 illustrates such a diagram. The simplest method of measuring transmission losses is to transmit a signal of zero db on the line and then measure the output at the desired points with a decibel meter. A decibel meter is an ammeter calibrated so that the scale reads directly in decibels. If the db meter indicates a reading of —10 db, then the line has a loss of 10 db at that point. This method, however, has two disadvantages: First, it is difficult to design a db meter sensitive enough to operate on the small amount of power present in a long transmission line; secondly, it is difficult to construct a meter that is accurate over a wide range of frequencies such as is employed in wire communications.

A method which overcomes these two difficulties is to amplify the signal to be measured by a known amount, and then to rectify the output to produce a direct current. The DC output may then be measured by a DC decibel meter. This method insures that sufficient power will be available to operate the meter and at the same time removes any of the inaccuracies that may be present because of the frequency. Instruments of this type, incorporating an amplifier, a rectifier, and a DC decibel meter in a single unit, are known as "direct reading transmission measuring sets." The amplifier of this set is provided with a control which enables the operator to vary the gain. The gain control is calibrated so that by combining the dial reading of the gain control with the reading of the db meter, the power level at the input of the instrument may be determined.

Correction of Transmission Losses

The following is a more detailed discussion of the methods by which the transmis-

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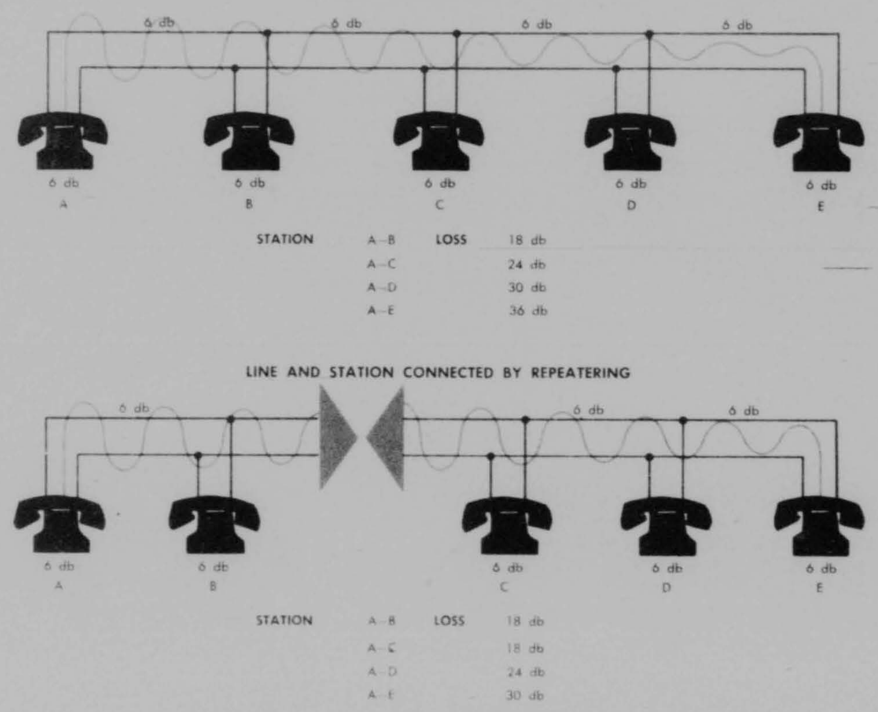

Figure 2-40 Transmission Loss

sion losses may be corrected. In the preceding paragraphs some of these have been briefly mentioned but it is necessary for the communications officer to have a more complete understanding of these methods.

The **attentuation** of a transmission line may be decreased by reducing resistance, capacitance, leakage, or any combination of these. The resistance of the circuits may be reduced by employing a larger gauge wire; the capacitance of the circuits may be reduced by increasing the spacing of the wires on the crossarm, and the leakage may be decreased by the use of a higher grade insulating material on the wires and the insulators. All of these methods greatly increase the cost of construction and therefore may be impractical. A method which is both simple and economical is that of loading.

Loading consists of increasing the inductance of the transmission line by adding inductance in series. This practice reduces the attenuation and thereby increases the range of communication. The practice of adding inductance to the line tends to equalize the attenuation at the different frequencies that are present in wire communication circuits, and as a result lessens the amount of frequency distortion in the circuit. In addition to these improvements, the loading of the line tends to make the characteristic impedance of the line remain more nearly constant with the changing frequency.

The most practical way of increasing the inductance of a line is to connect loading coils in series with each wire of the line at certain specified intervals. The line then is known as a "loaded line."

Although loading coils decrease the attenuation of the line over voice frequencies, they increase the attenuation at frequencies above the normal voice band, unless the coils are spaced at such close intervals as to be uneconomical and impractical. For this reason, lines which are designed to transmit a wide range of frequencies, such as are employed in a carrier system, are seldom loaded. Instead, repeaters are used to compensate for the attenuation.

The amount of crosstalk in a line depends to a great extent upon the design and construction of the particular circuits. Crosstalk tends to increase proportionately with length of parallel circuits, with an increase in strength and frequency of the transmitted signal. Circuits using repeaters increase the strength of the transmitted signals. Since carrier systems utilize repeaters on long lines and operate at high frequencies, the tendency for crosstalk is further increased.

Crosstalk may be reduced by the correct spacing of repeaters. If two circuits are close together at a point near a repeater station, and one circuit is carrying the weak current entering the input of the repeater, the circuit carrying the strong current tends to interfere with the circuit carrying the weak current. A practical remedy for this condition is to keep circuits carrying strong currents as far removed from circuits carrying weak currents as possible. Where this separation is not feasible, more repeaters may be added so that no repeater will be required to provide a very large amount of gain. This increases the number of repeaters required in the circuit. However, with each repeater producing less gain there will be a more nearly equal value of the currents flowing in the circuit at all times, and will tend to decrease the amount of crosstalk in the circuit.

On open-wire lines, crosstalk reductions depend mainly on three factors: resistance balance, configuration of the wires on the poles, and transpositions. Resistance balance is primarily a question of maintenance and usually presents no special problems. However, configurations and transpositions do require special consideration.

There are several types of configurations employed to reduce crosstalk. Insulators on crossarms are arranged so that individual

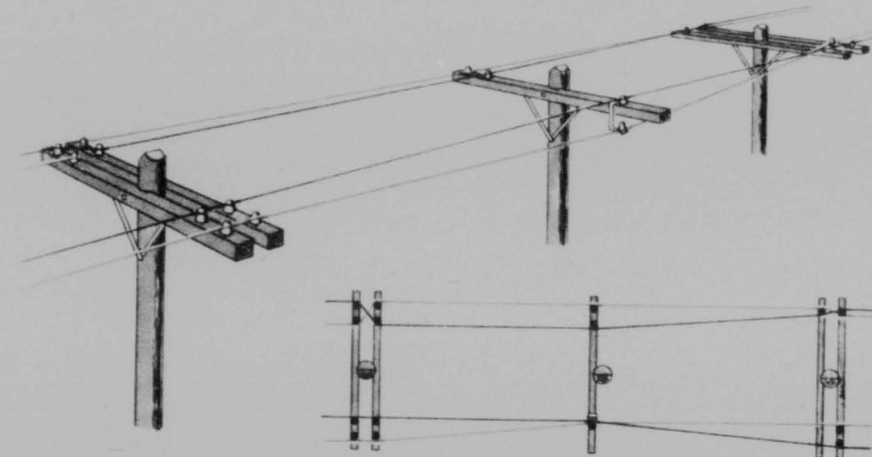

Figure 2-41 Types of Transposition

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pairs have a greater spacing. This configuration results in a decrease in the difference of the voltages induced, the voltages, which are now more nearly equal, tend to cancel each other, with a consequent reduction in crosstalk. A limitation of this method is the danger of closely spaced wires swinging together in the wind.

In spite of the many types of transpositions, the principle is the same. Wires are crossed over or transposed in a manner that the induced voltages tend to cancel, thus reducing crosstalk. The methods used in cable lines differ somewhat from those used on open wire lines. This is mainly because the wires in the cable are crowded closer together. In the cable, the wire pairs are twisted together and in turn, pairs are twisted to form a quad. Quads are in turn spiraled about the cable core. The principle cause of crosstalk in cables is the capacitance difference between the wires of the cable. Capacitance unbalance is reduced at the time of installation by testing cable quads at predetermined splices, then splicing quads with a high value of capacitance in one direction with a quad with a low value of capacitance in the other direction. The matching of quads in this manner reduces capacitance unbalance to a minimum and therefore greatly reduces crosstalk.

Field wire lines present no special problem in connection with crosstalk since the wires are wound spirally, effecting a continuous transposition.

Since noise, like crosstalk, is an induced effect, similar measures are used to reduce noise. However, since the principal source of noise is the paralleling of an electric power line, the methods of transposition are not adequate although they will provide some help in reducing noise. This may be more clearly understood by considering the special case created by power lines. The power line operates at much higher voltage and carries a much greater current than does the telephone line. Therefore, a greater magnetic field is created by the power line and it is consequently able to induce much greater currents in the telephone line. Whenever practical, the ideal way to eliminate interference from power lines is to avoid any parallel between power lines and telephone lines. In many cases, parallels with little separation cannot be avoided. For the normal distribution system of the electric utility, road distance separation should prove sufficient. For transmission systems, however, this will not prove adequate; greater separation will have to be effected in order to reduce the noise to a sufficiently low value to make the line usable. If adequate separation may not be attained, it may be necessary to make use of certain measures in addition to balancing and transposing the telephone conductors. These measures usually require the cooperation of the electrical utility. The particular techniques vary somewhat with each situation, but include such measures as rearrangement of the transformer connections, or insertion of filters in the power line to reduce the harmonics present in that source. Special configurations of the power line conductors provide a better electrical balance.

Although the attenuation in a line usually is undesirable, there are occasions when it is desirable. If the output of a repeater is greater than desired, attenuation is introduced intentionally. A resistance network, known as a "pad", is used to produce intentional loss in a circuit. Pads consist of resistance in series (series arms) and are designed to provide any required amount of loss. A pad has two properties: the amount of loss that it will produce in a circuit which is expressed in db; and the impedance it presents to the circuit, expressed in ohms. Since most of the telephone equipment is designed for 600 ohm impedance, pads are usually designed to have an input and output impedance of 600 ohms.

Filters are in many respects similar to pads. The principle difference between pads and filters is that pads are designed to produce approximately the same loss at all frequencies, while filters are designed to produce high losses at some frequencies and low losses at others. Filters are made up of inductors and capacitors, arranged to offer high losses to given frequencies. The three fundamental types of filters are the high-pass filter, the band-pass filter, and the low-

pass filter. The high-pass filter will pass all frequencies above a certain specified frequency. The low-pass filter will pass those frequencies which lie below a specified frequency. The band-pass filter will pass those frequencies which are within a specified frequency band.

Because frequency distortion occurs when the attenuation of a line is not the same at all frequencies, it sometimes becomes necessary to use a network to correct the unequal attenuation. Such a network is called an "attenuator equalizer" or simply "equalizer." Equalizers consist of inductors, capacitors, and resistors arranged in a network. The losses produced by the equalizer vary inversely with the loss of the line. Thus, if the loss in the line is high with the high frequencies, the losses in the equalizer will be low at these frequencies and high where the loss of the line is low. Equalizers are generally used with repeaters in such a manner that the weak signal passes through the equalizer prior to entering the repeater. This permits a more nearly even amplification over all frequencies employed on the line.

4. TYPES OF CIRCUITS

General

Wire circuits are classified in two ways: according to use, as either a trunk line or a local loop, and according to the type of transmission path employed.

A **trunk line** connects switchboards at two different points and is normally a high quality line since the distance between switchboards may be great. Considerable care must be taken with this type of construction in order to obtain the desired quality of transportation.

The **local loop** is a circuit employed to connect the subscriber's telephone to the switchboard. It is usually a short line and may not be as well constructed or have the same high qualities of transmission required of a trunk circuit.

The classification of circuits according to the transmission path employed is of great importance to the communications officer since a knowledge of this will permit him to make the best use of the wire facilities available to him.

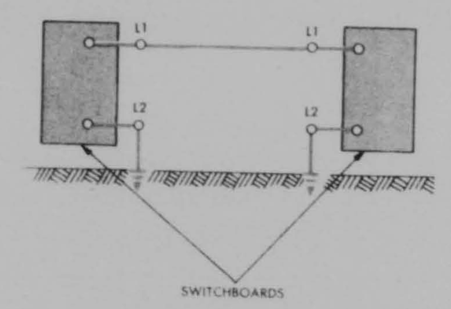

Figure 2-42 Ground Return Circuit

Unbalanced Circuits

Unbalanced circuits are those in which one side of the line has a greater resistance than the other. This type of circuit is employed primarily for economy of construction. The cause of unbalance is, normally, the use of ground return. There are two applications of this: the ground-return circuit and the simplex circuit.

Ground-Return Circuit. The ground-return circuit employs one wire as one side of the circuit and the earth as the other side of the circuit. Figure 2-42 illustrates this type of circuit. The ground-return circuit is inherently unbalanced, noisier, more subject to crosstalk, and messages over them are more easily intercepted than is the case with balanced circuit. A ground-return circuit requires that one wire only be installed and therefore may be constructed more rapidly and at the same time requires one-half as much wire to construct. At the same time, the circuit is more likely to fail completely if that one wire is damaged.

Simplex Circuit. Before discussing the simplex circuit, it is necessary to introduce the **repeating coil.**

Repeating coils are used in field wire systems to make possible the construction of simplex and phantom circuits for additional telegraph, teletypewriter, or telephone channels. The coils consist of two windings on a magnetic core, carefully balanced to pre-

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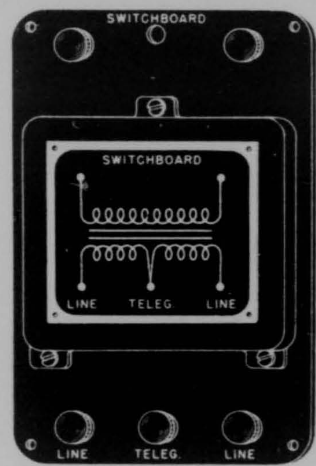

Figure 2-43 Repeating Coil C-161

vent crosstalk. The ends of one winding are brought out to two terminals, marked LINE, which are connected to the incoming wire line. The ends of the other winding are brought out to two terminals, marked SWITCHBOARD, which are connected to the switchboard line terminals. The midpoint of the line side of the coil is brought out to a fifth terminal, marked TELEG, that can be connected to provide a simplex or phantom circuit.

The coil commonly issued for use in the field is Coil C-161.

The simplex circuit is obtained by placing a repeating coil at each end of the metallic circuit. Usually the coil at each end is located in the line as close to the switchboard terminal strip as practicable. The binding posts marked **LINE** are connected directly to the line, and those marked **SWITCHBOARD** are connected to the desired line terminals on the switchboard. The telephone circuit is completed inductively through the coil. The binding post marked TELEG is connected to one line terminal of the telegraph set. Usually this line to the telegraph set is referred to as the telegraph leg. Ordinarily the other line terminal of the telegraph set is connected to a suitable ground near the instrument.

When a telephone is installed on a simplex line without a switchboard, the repeating coil terminals marked SWITCHBOARD are connected directly to the telephone.

Switchboards integrally equipped with repeating coils and terminal strips have the repeating coils permanently connected between the switchboard terminal strips and certain line units. The simplex circuit is then obtained by connecting the desired line to the proper line terminals on the switchboard, and running the telegraph leg from the corresponding telegraph binding post to the telegraph set.

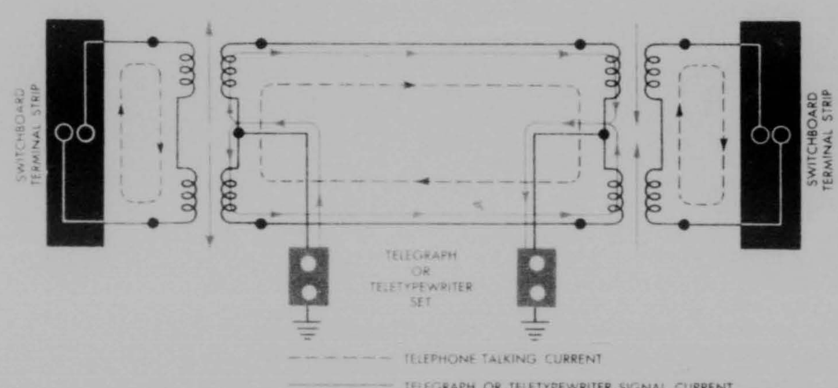

Figure 2-44 Simplex Circuit

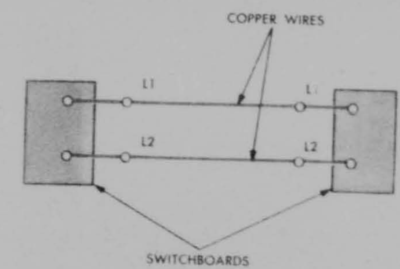

Figure 2-45 Balanced Circuit

Balanced Circuits

The balanced circuit is completely metallic. It requires two wires to make it complete. It derives its name from the fact that it has the same characteristics on each side of the line. It is the most commonly employed type of line since it has very good transmission characteristics, and, therefore, affords a high quality of service. Figure 2-45 represents the balanced circuit.

Phantom Circuit

A phantom circuit may be constructed from two metallic circuits and four repeating coils, two at each end of the lines. The two binding posts marked TELEG at each end of the lines form the phantom circuit, and may be connected to an unused pair of line terminals at the switchboard.

If desired, the phantom circuit thus formed may be simplexed itself to obtain a telegraph circuit in the same manner described in the preceding paragraph for a single metallic circuit. This requires the use of an additional repeating coil at each end of the lines.

5. TESTING AND MAINTENANCE

When outside wires develop faults such as contacts with ground, short circuits, crosses with other circuits, or open circuits, these faults may be located by using test equipment. The test equipment consists of voltmeters and Wheatstone bridges, in combination with tones, ringing voltages, and DC voltages. The test equipment employed by the military is specially packed for field use and contains many different combinations of the basic test equipment available. In addition,

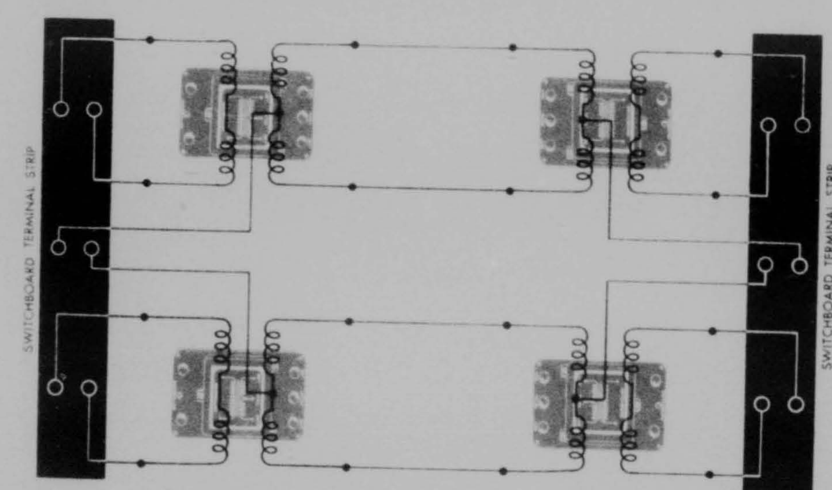

Figure 2-46 Phantom Circuit

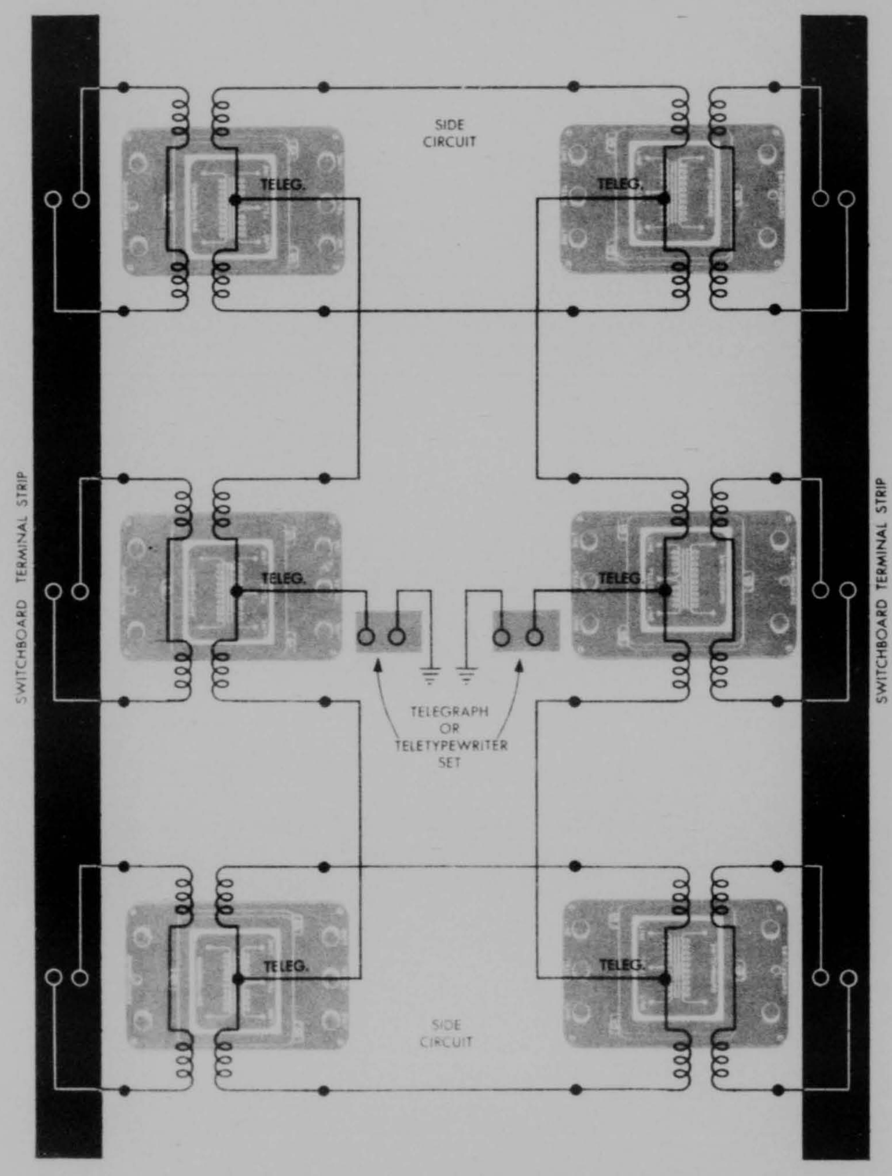

Figure 2-47 Simplexed-Phantom Circuit

much of the same equipment may be used to test for faults in central station lines and equipment. After the faults have been localized, they may be cleared by any of the techniques indicated and with the aid of the various maintenance equipment which is available for this type of work.

The tests which can be performed with test equipment installed in telephone centrals may be briefly summarized as follows:

a) Test calls can be originated and answered on magneto and common-battery loops.

b) Tests can be made with a voltmeter to check the continuity of a circuit and to detect accidental grounds, short circuits, crosses, and opens.

c) Ringing voltage can be applied to a circuit as a step in detecting grounds, short circuits, or opens.

d) The capacitance from line to ground or to another line can be indicated by the swing of the voltmeter needle in combination with the initial application of a potential through the voltmeter to the line.

e) Voltages may be measured.

f) Conductor loop resistance and insulation resistance can be measured with a voltohmmeter or Wheatstone bridge.

g) Approximate locations of open circuits on open-wire lines can be estimated from the capacitance tests with a voltmeter.

A small central with a fixed plant switchboard ordinarily will be equipped with a portable Wheatstone bridge for use in finding faults on the lines and for other test procedures. At the terminal of a main cable route there will generally be a somewhat larger test set for testing purposes, while the large centrals will be provided with a built-in test board.

When a loop or trunk circuit fails, the following procedures may be adopted to clear the trouble. The trouble is analyzed by making overall ringing tests and talking tests. Then specific tests are made to localize the trouble on the circuits which fail on the ringing and talking tests. In the smaller centrals, these tests may be made with a voltmeter at the switchboard. While in larger centrals, they may be made with a test unit or test board. The line is sectionalized and analysis tests are made on each section to determine its condition. When the section with the fault is discovered, the test board nearest that section is employed to locate the fault more exactly. After the fault has been located as closely as possible by these electrical means, it is necessary to patrol the line and physically locate and clear the fault.

Test and control board equipment provide jacks and patching cords for removing circuits from service as may be required for trouble tests, routine tests, or other transmission measurements. Furthermore, it provides arrangements for monitoring and talking on the lines. The monitoring jacks may be arranged in some test boards to make the circuits under test busy at associated switchboards. This avoids interference between the regular traffic and test calls and gives full control of the circuit being tested to those making the tests. In centrals where these automatic make-busy features are not provided, it will be necessary for the testing personnel to ask an operator to make the circuit busy at the switchboard.

SECTION 5 - FUNDAMENTALS OF CARRIER TRANSMISSION

1. GENERAL

A most important military development in the field of wire communications is carrier transmission. This development is a major step in the satisfaction of the military management requirements of time, space, materiel, and personnel through the economies it effects. These savings will be further discussed in the section below. In addition, car-

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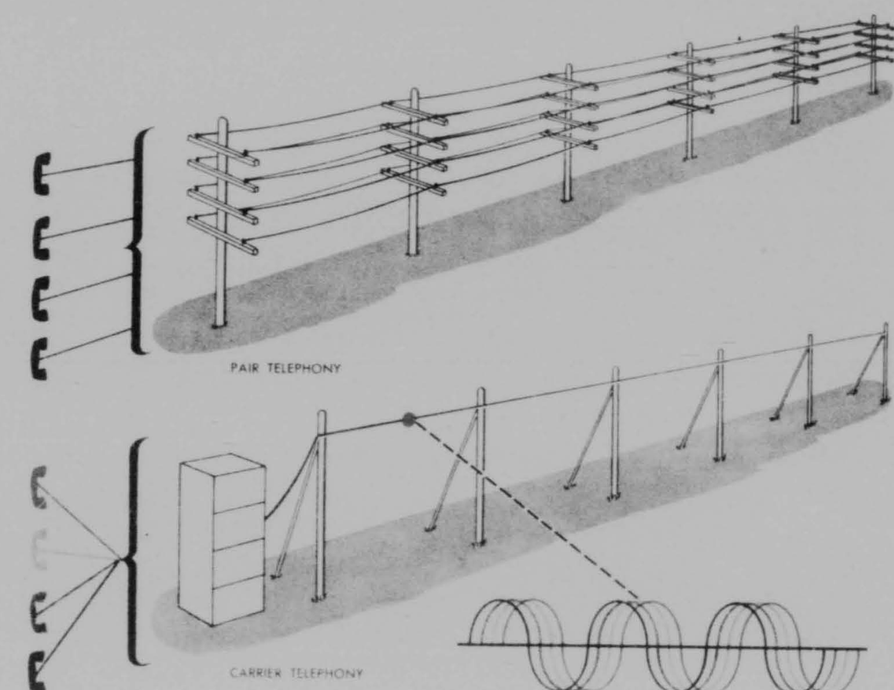

rier transmission adheres to the communications principles of reliability, economy, flexibility, security and mobility.

Purpose

Theoretically, a transmission line is capable of transmitting frequencies from zero to infinity. However, because of practical considerations, a standard transmission line is capable of efficiently transmitting frequencies ranging from zero to approximately 150,000 cycles per second. The voice frequency range is from 200 to 2,700 cycles per second, so it is apparent that only a very small portion of the potential frequency range capabilities of the line is utilized when a single voice conversation is transmitted over the standard transmission line. In effect, the entire frequency range above 2,700 cycles is wasted. However, there is a way to reallocate or space out several 2,500 cycle voice-frequency bands or voice channels in this otherwise wasted region, making it possible to transmit several conversations simultaneously without mutual interference and thus utilize more fully the capability of the transmission line. This reallocation, or spacing out, of the normal voice channel to obtain several facilities over the same line is accomplished by carrier systems.

It is readily seen that superimposing of several voice-frequency channels on a single transmission line will have some immediate advantages. The chief advantage is the more economical usage of line construction materials. The saving in wire alone will often more than justify the use of carrier systems. Additional economies in time, personnel, and space further justify the use of this system since wire construction is time consuming,

requires large numbers of men who are not always readily obtainable, and includes the necessity for storage and operating space for vehicles, as well as equipment.

2. PRINCIPLES OF OPERATION

Carrier equipment and systems were originally developed for commercial use. The advantages of carrier systems were recognized by the military, and packaged items were designed for use by tactical forces in the field. Because of the military adoption of the carrier in wire communications, it is worthwhile to discuss the basic principles involved. To understand the method by which many channels of telephone and telegraph are obtained over the same wire which formerly provided a single channel, an explanation of carrier current, modulation, and demodulation is necessary.

Carrier Current

An alternating current of a constant predetermined frequency is generated at the terminal of a carrier system by an oscillator. This current is known as "carrier" current because it serves to carry the superimposed voice currents. The process of superimposing the voice currents on the carrier current is known as "modulation", and the device which makes this possible is the modulator. All that results from impressing the voice frequency on the carrier frequency is a reallocation or shifting of the voice frequency range to some other frequency range. For example, the normal 2,500 cycle band of voice frequencies is, as stated previously, from 200 to 2,700 cycles. However, this band of frequencies can be shifted by the use of carrier frequencies so as to occupy the frequency range from 3,100 to 5,600 cycles. Therefore, in this case, it is possible to transmit two messages simultaneously on the same transmission line without mutual interference; one message will occupy a frequency range from 200 to 2,700 cycles while the other will occupy the range from 3,100 to 5,600 cycles. If additional carrier frequencies were generated with a sufficient separation between each band so that they would not interfere with each other, it would be possible to transmit more messages over the same transmission line. All these messages being transmitted over the carrier system and a common transmission line behave as if they were being transmitted over separate transmission lines. At the receiving end the intelligence is separated by a process called "demodulation". This process is the reverse of the process at the sending end.

Modulation

When two different frequencies are combined in a modulator, the original frequencies appear at the output of the modulator together with several other frequencies. Two of these other frequencies are of particular concern: the first is the sum of the original two frequencies and the second is the difference between the two original frequencies. The sum of the two original frequencies is known as the "sum frequency", and the difference between the original two frequencies is known as the "difference frequency". Hence the four frequencies of particular concern which appear at the output of the modulator are: the voice frequency, the carrier frequency, the sum frequency, and the difference frequency. For example, if a 1,000-cycle frequency is combined with a 10,000-cycle frequency, the output of the modulator contains the two original frequencies of 1,000 and 10,000 cycles, the sum frequency of 11,000 cycles, and the difference frequency of 9,000 cycles. The sum and difference frequencies are known as the upper and lower modulation components, or, more commonly, as the upper and lower sidebands. Either the upper or lower sideband can be used to carry the message currents. Figure 2-48 is a block diagram showing how the modulator combines two different frequencies and the filter which permits only the desired sideband for transmission to pass.

Demodulation

In a sense, demodulation is remodulation. In demodulation, the transmitted sideband is combined with the frequency of the original carrier to reconstruct the original transmitted signal. To continue the example given above, if the lower sideband of 9,000 cycles

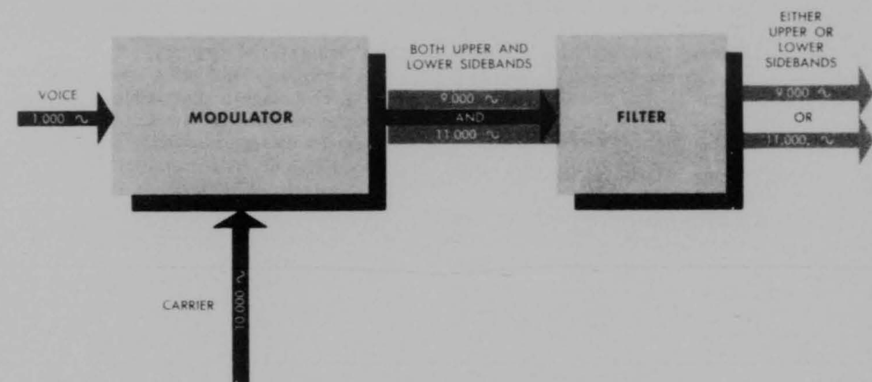

Figure 2-48 Formation of Upper or Lower Sidebands

were transmitted, it would be recombined with the 10,000-cycle carrier frequency at the receiving point where demodulation takes place. The recombination again produces the sum and difference frequencies of 19,000 and 1,000 cycles. A filter removes the undesired frequencies and permits the desired frequency of 1,000 cycles to pass. Hence, in demodulation the received sideband is combined with the carrier frequency of the original signal to reconstruct the original signal that was superimposed upon the carrier frequency. Figure 2-49 is a block diagram illustrating demodulation.

Carrier Filters

A typical carrier system is shown in Figure 2-50. A hign-pass filter and a low-pass filter are combined in a single unit known as a "line filter" which is connected to the line to separate the higher frequency carrier currents from the lower frequency voice currents. At the switchboard side of the carrier terminals, hybrid coils separate the transmitting and receiving branches of the carrier circuit. Low-pass filters are used at the inputs of the modulators to eliminate all frequencies outside of the voice range. The

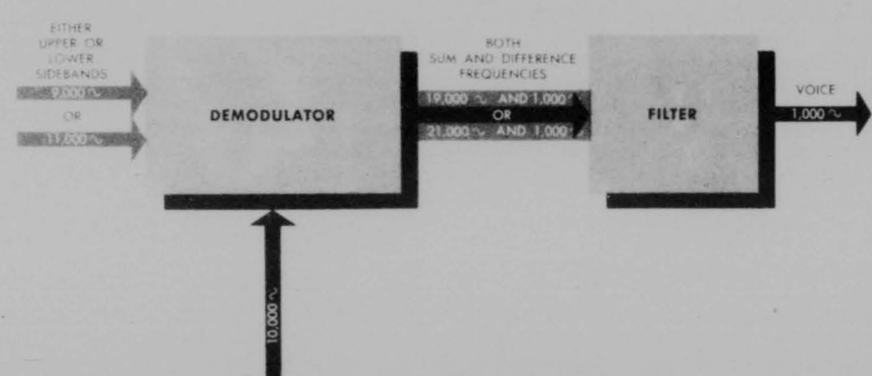

Figure 2-49 Demodulation of Sidebands

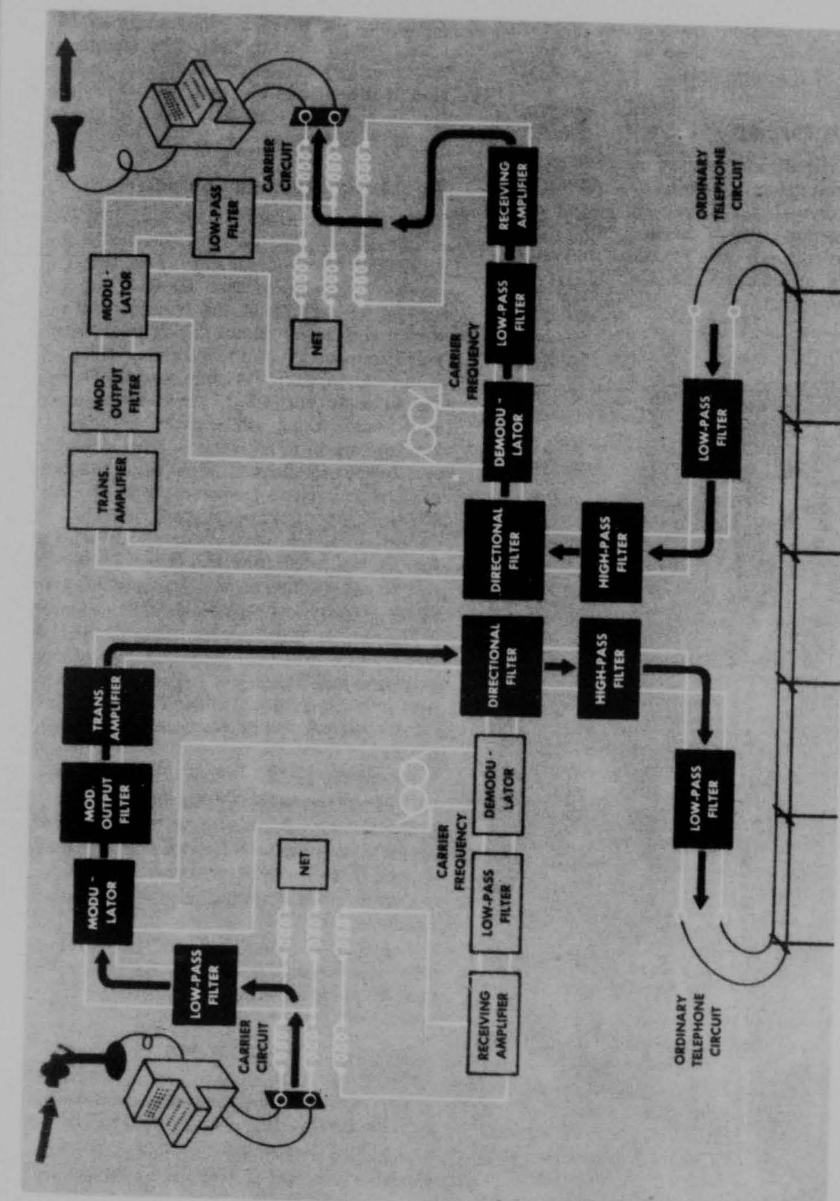

Figure 2-50 Operation of a Single Carrier Channel

modulator out-put filters eliminate all undesired modulation components. Likewise, low-pass filters are used in the receiving branch of the terminals.

3. EQUIPMENT

The circuit components of telephone terminal equipment have been described in some detail above because they are present in all major components of carrier equipment. We will now examine the functions and characteristics of separate items of military carrier equipment.

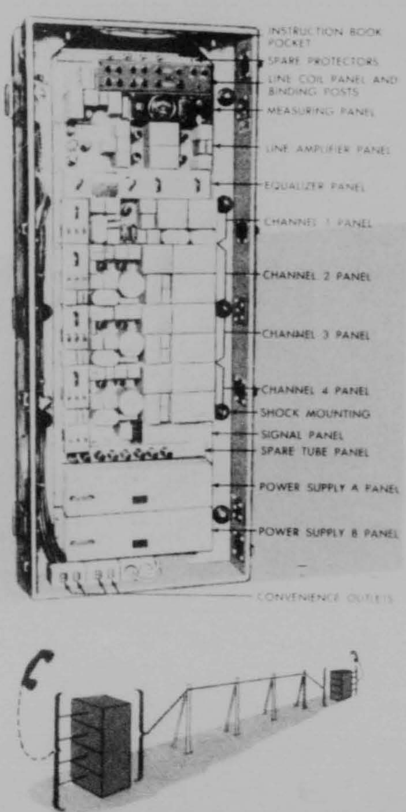

Figure 2-51 Telephone Terminal CF-1-A

For purposes of discussion, carrier equipment may be divided into three classifications: terminal equipment, line equipment, and ringing equipment. A general description of these types together with their function in a carrier system is given in the following paragraphs.

Telephone Terminal Equipment

Telephone terminal CF-1-( ) is the basic equipment of any carrier system. It provides four telephone channels; channel 1 at voice frequency, and channels 2, 3, and 4 at carrier frequencies at the transmitting terminal, shifted by demodulation back to the voice frequencies at the receiving terminal. Any or all of the CF-1 channels may be employed with the CF-2 telegraph terminal equipment (which will be described later) to transmit up to four teletypewriter messages per telephone channel. The four channels require an over-all frequency band of about 200 to 12,000 cycles per second, each channel occupying about 2,600 cycles. Each of the four is separated from the others by filters. A general outline of the features of telephone terminal CF-1-A follows:

Means for terminating the spiral-four cable,* with protection against lightning and extraneous voltages. (*CF-1's are generally used with spiral-four cable. The spiral-four carrier system will be discussed later in this chapter.)

Means for providing two DC simplex circuits over the spiral-four cable pairs.

Modulating, demodulating, filtering, and amplifying equipment for one voice-frequency and three carrier-frequency channels.

Common transmitting amplifier for four channels.

Common receiving amplifier for four channels with adjustable equalization to compensate for the attenuation characteristics of the spiral-four cable.

Means for monitoring and talking on all channels.

Test oscillator and transmission measuring circuits for making line-up adjustments.

Signaling device for communicating with repeater stations and other terminals over one simplex circuit.

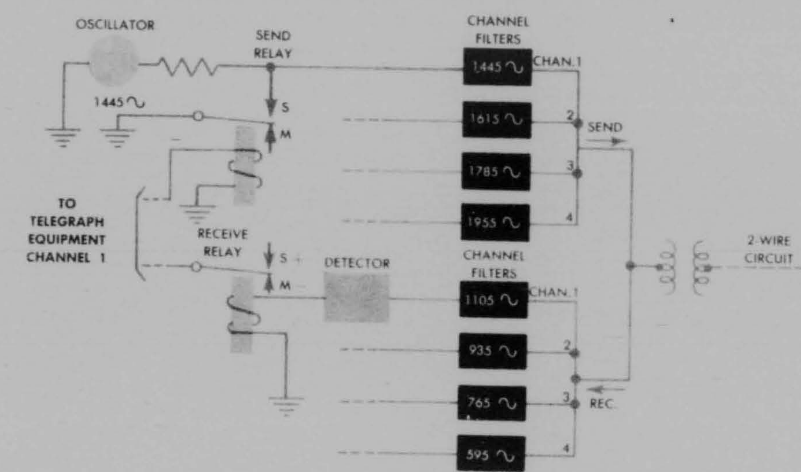

Figure 2-52 Elementary Block Diagram of Telegraph Terminal CF-2-C

One power supply for line amplifier signal circuit, and one for channel amplifiers, modulators, demodulators, and test oscillator. Operation on AC supply of 110-125 or 220-250 volts, 50-60 cycles with automatic fall-back to operation from a 12-volt storage battery during AC power failure.

Telegraph Terminal Equipment

If four (or fewer) telegraph channels are required in a carrier system, a telegraph terminal equipment CF-2-( ) is added to the CF-1 at each end of the system. A general outline of the features of this equipment follows:

It is suitable for two-wire operation over any telephone circuit having a net loss of not greater than about 25 db and uniform loss-versus-frequency characteristics over the range of 300 to 2,500 cycles.

Provides four two-way voice-frequency telegraph paths, each capable of teletypewriter operation at speeds of 60-75 words per minute.

Provides a DC circuit in each of the four channels for half duplex or full duplex operation.

Contains meters and controls for checking and adjusting telegraph channels for optimum operating conditions.

Is equipped with telegraph relay testing features, and tools necessary for relay maintenance.

Includes positive and negative 130-volt rectifiers in each bay. Each rectifier contains an automatic reset device to protect the rectifier tubes in case of AC line failure. AC power at 103-128 or 207-253 volts, 60-60 cycles, is required for the operation of these units. No provision is made for emergency operation from storage batteries.

The CF-2-B has the same features as the CF-2-A, except that it is assembled into one bay, or case, instead of two.

A second item of terminal equipment often used in carrier systems is Telegraph Terminal CF-6 which provides two additional channels for voice-frequency telegraph operation. A CF-6 may be used separately or in combination with a CF-2. In the latter case, its four frequencies (two per channel) are spaced with the eight frequencies of the CF-2, 170 cycles apart in the voice range from about

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340 to 2,400 cycles. Therefore, when four-wire operation is used, a CF-2 and CF-6 can combine to operate twelve two-way telegraph circuits, since transmission in each direction is over a separate line pair and each of the twelve frequencies can be transmitted in both directions. All of these telegraph circuits require only one channel of the associated Telephone Terminal CF-1. This example gives a true indication of the value of carrier.

Repeater Equipment

At the points in a carrier system where repeaters are required, Repeater CF-3-A is connected in the four-wire line. The repeater has power equipment similar to that at the terminals and provides a separate equalizer and amplifier for each direction of transmission. When required for the maintenance of the system, facilities are provided for talking over channel 1. A general outline of the features of Repeater CF-3-A follows:

Means for terminating the spiral-four cable in each direction, with protection against lightning and extraneous voltages.

Means for providing two DC simplex circuits in each direction over the spiral-four cable pairs.

Two amplifiers, one for each direction of transmission, common to all four channels, with variable equalization for the attenuation characteristics of the spiral-four cable.

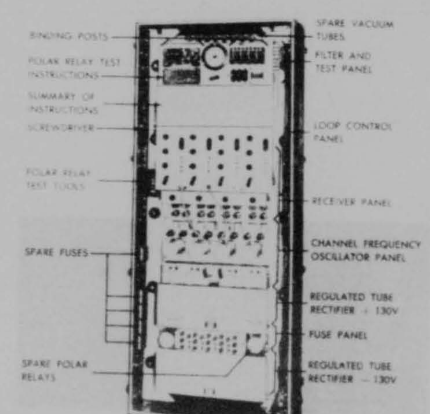
Transmission measuring circuit for making line-up adjustments.

Means for monitoring and talking on channel 1, the voice-frequency channel, without interfering with the other three channels.

Signaling device for communicating with terminals and other repeaters over one DC simplex circuit.

Power supply for operation on 110-125 or 220-250 volt, 50-60 cycle AC, with automatic fall-back to 12-volt storage battery operation during AC power failure.

Repeater CF-5 is used in conjunction with 2-wire facilities. This repeater makes possible greater transmission distances in a circuit which was converted from four-wire to two-wire operation at or near each terminal. It is composed of two independent amplifying circuits, one of which is associated with the AB (terminal A to terminal B) direction of transmission of 20,850-32,250 cycles, and the other with the BA direction of 200-11,600 cycles. Filtering and equalizing circuits are associated with those of amplification and transmission measuring controls are also included. Signaling and talking circuits are also provided with this repeater.



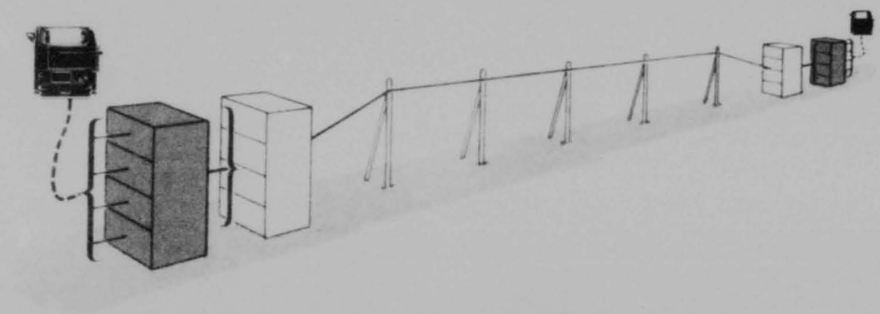


Figure 2-53 Telegraph Terminal CF-2-B

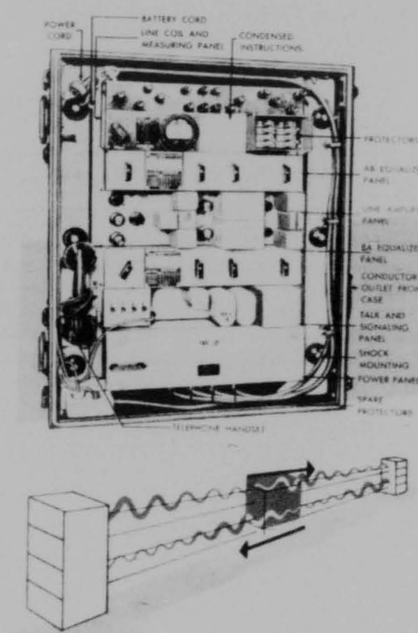


Figure 2-54 Repeater CF-3-A

Converter Equipment

At the junction of two-wire and four-wire facilities in a carrier system, a converter CF-4 is placed in the line to effect the change-over. It permits operation of the four channel system, discussed above, over a single pair of nonloaded open wires. A frequency range of 200-11,600 cycles is used in one direction of transmission, and a range of 20,850-32,250 cycles is used in the opposite direction. The CF-4 does not contain a means for talking over the system since usually it will be located adjacent to its associated terminal. If these units are some distance apart, a separate talking channel may be provided by using Telephone Units EE-105 or separate field wire facilities.

Carrier Hybrid CF-7 is a converting device for connecting a two-wire line to either a Telephone Terminal CF-1 or a Repeater CF-3, both of which are designed for four-wire operation. With this equipment, which requires no power and is installed in a small

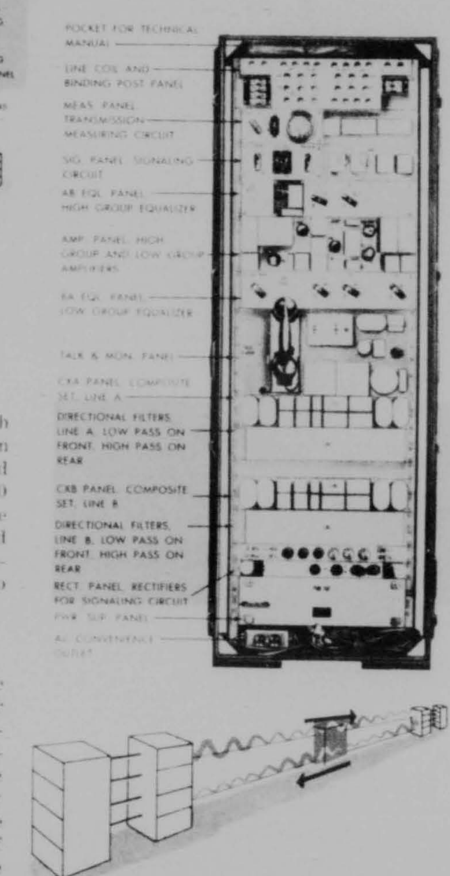


Figure 2-55 Repeater CF-5 (2-Wire)

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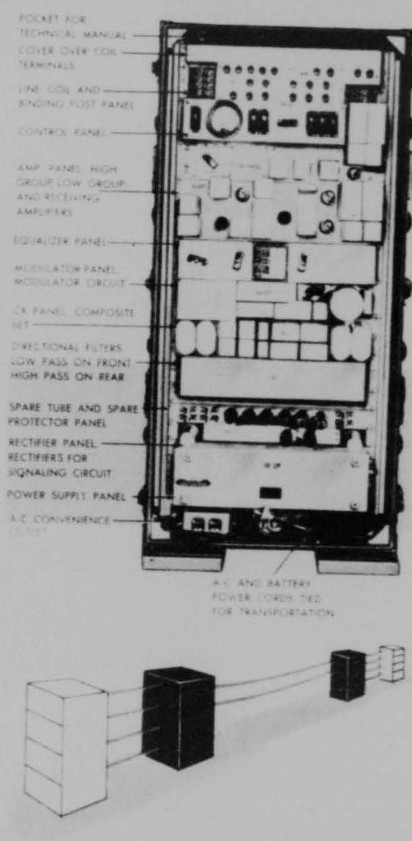

Figure 2-56 Converter CF-4 (2-Wire to 4-Wire)

carrying case, four two-way telephone circuits can be obtained over a single pair of wires. In addition, two grounded DC telegraph circuits or one of these and a DC signalling circuit may be operated over the pair. In place of one of the telephone circuits, four voice-frequency telegraph channels can be made available by applying CF-2's at the telephone terminals.

Ringing Equipment

With the development of carrier equipment, a device which could ring or signal over the voice frequencies employed became necessary. The low frequency (16 and 20 cycle) ringing current supplied from switchboard and magneto telephone sets was not suitable for ringing, so Ringer Equipment EE-101 was incorporated in carrier systems for this purpose. When installed at the terminals and connected between the switchboard or telephone set and the line, the ringer equipment responds to the low-frequency current, rectifies and filters it at 20 cycles, raises it to voice-frequency by means of a 1000/500 cycle oscillator or vibrator, and sends it out over the line. The ringer at the receiving station operates in reverse to convert the note back to the low frequency required to energize the switchboard or telephone.

4. CARRIER SYSTEMS, GENERAL

Carrier operation is desirable since it permits maximum use of existing facilities, reduces the amount of open-wire construction, and saves in shipping space and weight of materials. The carrier equipment can be transferred readily from one location to another as the requirements change. The time required to establish a given number of carrier circuits on existing transmission lines is much less than is required to string additional wire facilities.

Carrier systems are of three types which differ only in the method of handling the two-directional transmission of messages as required for telephony. These three kinds are physical four-wire, balanced two-wire, and

Figure 2-57 Carrier Hybrid CF-7

Carrier system	No. of circuits	No. of pairs	Type of line	Type of operation	Approx. frequency range (kilocycles)	
					A to B	B to A
Spiral-four	4	2	CC-358-( ) or open wire	Physical 4-wire	0.2-11.6	0.2-11.6
Carrier hybrid	4	1	Open wire	Balanced 2-wire	0.2-11.6	0.2-11.6
Open wire converter	4	1	Open wire	Equivalent 4-wire	20.8-32.2	0.2-11.6

Figure 2-58 Carrier Systems

equivalent four-wire. The particular type used has important reactions on the application and layout of carrier systems. All three methods are employed with tactical equipment. Fixed plant carrier systems using packaged equipment (more or less standard commercial equipment) work only on the equivalent four-wire principle.

The physical four-wire system uses separate pairs of wires and the same band of frequencies for both directions of transmission. The system uses two independent one-way transmission paths like the ordinary four-wire telephone circuit except that the frequency band extends beyond the voice range. Physical four-wire systems are used for carrier on cables because this results in the lowest practicable top frequency and lowest attenuation for a given number of circuits. When used on open-wire circuits, physical four-wire systems are subject to high crosstalk between high signal strength outgoing currents of one system and low signal strength incoming currents of the same frequency in another system, unless repeater spacings are suitably reduced.

The balanced two-wire system requires only one pair of wires for operation. It uses the same frequency band for operation in both directions. Hybrid coils and balancing networks are used at terminals and repeater stations to separate the two directions of transmission. The transmission path between terminals is like an ordinary two-wire telephone circuit except that higher frequencies are transmitted. Freedom from instability and ringing is obtained by the balance between the lines and networks and by use of short repeater sections (closer spacing of the repeaters) and with only moderate gains at each repeater. Balanced two-wire operation is of use principally on open-wire lines but may be applied to other types for short distances. The number of balanced two-wire carrier systems which can be worked on an open wire line, without danger of high values of crosstalk between different systems, will depend on the repeater spacing, the type of line, and other factors.

The equivalent four-wire system uses only one pair of wires but the frequency bands for the two directions of transmission are different. Separation of the two directions of transmission at repeaters is accomplished by means of filters. This avoids the disadvantage of balanced two-wire operation while requiring only one pair of wires and retaining all of the transmission advantages of a four-wire system. However, these advantages are gained at the expense of more than doubling the top frequency of the system. For this reason, equivalent four-wire operation is normally used only on open-wire lines. Since a given frequency band always transmits in the same direction for any system on the line, crosstalk is of the far-end type (originates at the far end of the line). Therefore, repeaters of high gain may be used on a line with suitably designed transpositions.

5. TACTICAL CARRIER SYSTEMS

Some types of tactical carrier telephone systems and the types of lines on which they are normally used are tabulated in Figure 2-58. A discussion of several of these types follows below:

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Spiral-Four

The basic equipment of the spiral-four carrier system or the 100-mile spiral-four system, includes the Telephone Terminal CF-1, Repeater CF-3 and the necessary cable.

Spiral-four carrier equipment is designed basically for use as a physical four-wire system on Cable Assembly CC-358. Figure 2-59 shows schematically the arrangements for nonrepeatered and repeatered circuits.

Each system provides one voice-frequency and three carrier telephone circuits in the frequency range 200-11,600 cycles. Transmission characteristics permit 6-db repeatered circuits about 150 miles long when the cable is installed as an aerial cable or laid on the ground, or about 400 miles long when it is buried. Transmission factors limiting the length are loss variations caused by temperature changes and noise. In practice, buried cable lengths have been considerably less than 400 miles. Normal repeater spacings are about twenty-five miles and are limited by noise and available repeater gain. When noise is low, somewhat longer spacings can be used with some complications in maintenance.

When no intermediate repeaters are used, as in Figure 2-59a, circuit lengths up to thirty-five miles or more may be used by increasing the transmitting output at the terminals. Means are provided in the terminal equipment for accomplishing this gain. Under favorable noise and crosstalk conditions, single section systems can be operated for distances of fifty-five miles at 6-db net loss or eighty miles with a 30-db net loss. The gain of the terminal is sufficient for this purpose. When these extremely poor conditions are encountered, singing may occur in the spiral-four cable.

The two DC channels are provided over the

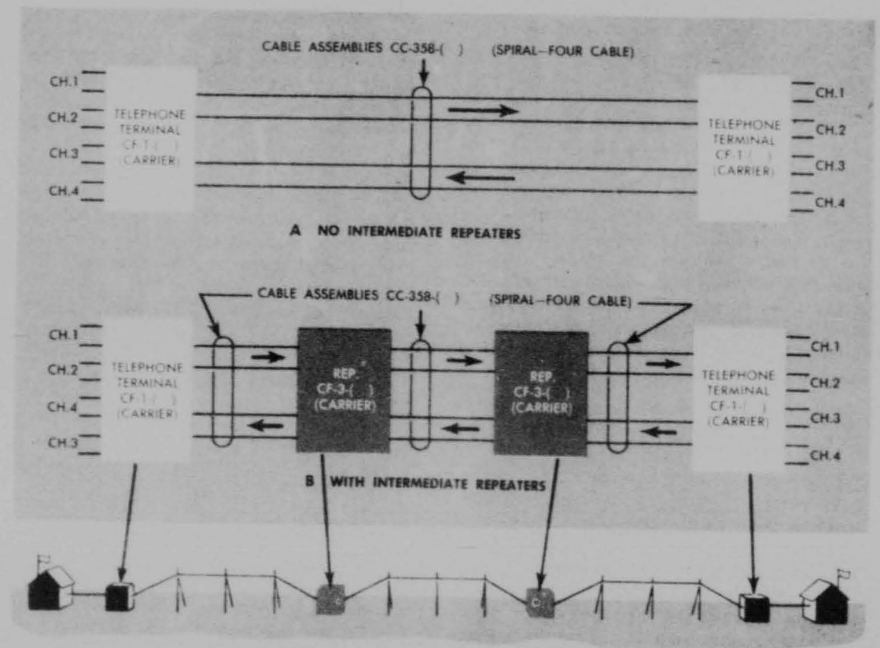

Figure 2-59 Spiral-4 Carrier Systems

two simplexes of the cable. Normally, one of these is used as a signaling channel to call the intermediate repeater attendant so that the other may be used for a telegraph circuit by one or two repeater sections.

The spiral-four system may be used on an emergency basis over two pairs of nonloaded Wire W-143 with repeater sections about fourteen miles in length. There are some restrictions on the use of W-143 for this purpose, such as its characteristic of capacitance unbalance, which may give noisy operation in certain areas having high static noise levels.

The spiral-four system can be used as a physical four-wire system on two open-wire pairs. The method of setting up such a system is the same as for the spiral-four cable system, except that the instructions with the equipment do not give typical equalizer settings for open-wire circuits. However, these settings may be determined during the line-up tests.

The transmission lines used with a carrier system may be combinations of open-wire, spiral-four cable, or Wire W-143 without serious effects on transmission except for some increases in the system losses. This makes the system useful in forward combat areas where well-constructed open-wire lines may not exist. Single systems may be operated on a nonrepeatered basis for lengths of 100 miles or more of open-wire circuits, giving four circuits on two pairs of wires. Circuit lengths may be increased by the use of repeaters. Two or more systems on the same line lead to crosstalk difficulties and require much shorter section lengths and repeater spacings for high grade transmission performance.

Carrier Hybrid Systems

Carrier Hybrid CF-7 which already has been discussed, may be combined with spiral-four equipment for balanced two-wire carrier operation using the same frequency band for each direction of transmission over open wires. This saves one pair of wires as compared with the physical four-wire system of operation, but places certain restrictions on the length of the repeater sections and the required regularity of line construction. Carrier Hybrid CF-7 includes a repeating coil hybrid, a balancing network, protectors, and a composite set for deriving two DC telegraph channels. Figure 2-60 shows by block diagram the lay-out of a carrier hybrid system.

Repeater section lengths must be kept short in this system to avoid singing difficulties. On well constructed lines with small irregularities, nonrepeatered circuits may be worked for sixty-five miles at 61-db net loss and 135 miles at 30-db net loss on 80 mil copper-steel pairs. Longer lengths may be operated with repeater spacings of about fifty miles on the 80 mil copper-steel wire. If the lines are damaged or poorly constructed, and have changes in wire spacing or gauge, or have short lengths of inserted cable, the usable gain will be reduced. Such irregularities may reduce the maximum length of

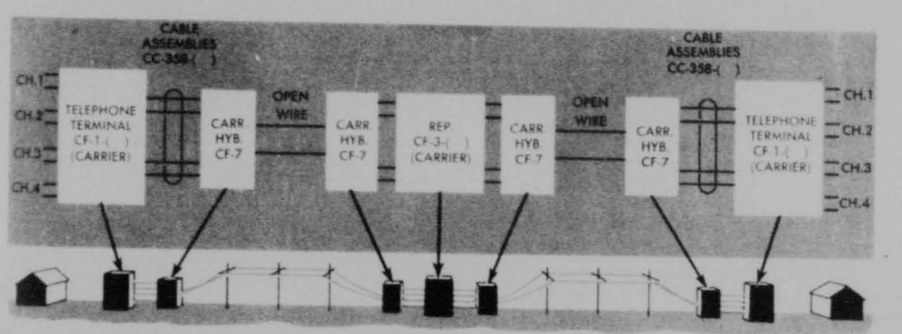

Figure 2-60 Balanced 2-Wire Carrier Hybrid System

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nonrepeatered circuits to not more than 45 miles at 6-db net loss and 115 miles at 30-db net loss. Irregularities in line construction are likely to be more common in forward areas and this characteristic of the carrier hybrid system should be allowed for in laying out systems in such areas.

If more than one carrier hybrid system is operated on a line, near-end crosstalk will occur between oppositely directed paths. On new carrier transposed lines of military construction, it will be possible generally to operate two carrier hybrid systems per cross-arm within the permissible crosstalk performance in forward areas. Existing lines may have poor crosstalk characteristics and operation of a number of systems will generally involve accepting higher crosstalk, increased circuit losses, or reduced repeater spacings.

The carrier hybrid system can be used on Wire W-143 or spiral-four cable for moderate distances. If both pairs of the spiral-four cable are used for these distances, crosstalk between the two systems will approach the maximum tolerable for forward areas. If one pair in the spiral-four becomes damaged, operation on a balanced two-wire basis in the faulty section can be used as an emergency measure.

The carrier hybrid system can be converted readily to a physical four-wire system or vice versa, especially in the case of nonrepeatered systems. This allows considerable flexibility in the use of the two systems. Where sufficient pairs are available, physical four-wire circuits provide a more stable and less vulnerable system with wide latitude in the makeup of the wire line. The carrier hybrid system is for use where pairs are at a premium and the distance to be spanned is within the capabilities of the system as limited by its particular line irregularities. Use of the system on very irregular lines in forward areas is possible on a single section basis provided no attempt is made to insert large amounts of gain; that is, the system may be used to yield more circuits on a pair of wires but not to increase the range by any great amount in such cases.

The carrier terminal and its associated hybrid coil may be separated and connections between the two made on a four-wire basis. This is illustrated in Figure 2-60, where spiral-four cable is shown connecting the terminals to the hybrids. This separation of the two units of equipment may be found desirable to avoid long cable lengths between the hybrid and the open-wire line. For example, it may be desired to place the terminal equipment in a less exposed place so that it may be camouflaged. However, this separation should be avoided whenever possible, since it tends to make the adjustment of the balancing network in the hybrid awkward.

Pair-Per-System Operation of Telephone Terminals

An emergency method for operating over open-wire lines on a pair-per-system basis is shown in Figure 2-61. This is an emergency arrangement for use only when the carrier hybrid and the open-wire converter systems are not available, and there are not sufficient pairs available to permit physical four-wire operations. Again, the carrier principle of using more than one frequency of one pair is employed.

It is not possible in this system to insert gain at either terminal, as this would cause circuit instability and singing. Simultaneous transmission in both directions is possible without encountering these interferences, provided the correct dial settings are made at each terminal. With these settings, the overall net loss of each channel would exceed the line attenuation by about 9 db. If properly adjusted, the circuits will not sing under any line conditions.

The circuit lengths with this system are limited to about twenty-five miles on 80 mil copper-steel wire for circuits having 18-db net loss, and about sixty miles for point-to-point circuits with 30-db net loss. Distances about three times as great may be spanned on 104 mil copper wire. Any inserted cable would reduce these lengths by the insertion loss of the cable.

Open-Wire Converter System

The open-wire converter system is an equivalent four-wire system, designed for operation over open-wire pairs without the limitations of the physical four-wire and carrier hybrid systems. This system uses the Converter CF-4 (Figure 2-56) and the Repeater CF-5 (Figure 2-55) in conjunction with the Telephone Terminal CF-1-51C.

Figure 2-62 shows a block diagram of a repeatered open-wire converter carrier system. The transmission over the open-wire line in one direction is 200-11,600 cycles, while 20,800-32,200 cycles is employed in the other direction for transmission. Converted to kilocycles these frequency spans read 0.2-11.6 and 20.8-32.2.

The telephone terminal equipment is connected over two pairs of wires to the converter and then to the open-wire line. At the converter on one end of the line, the band of frequencies used to transmit the voice currents is the normal of 0.2 to 11.6 kc. However, the frequencies employed at this end for the reception of incoming currents occupy the band from 20.8 to 32.2 kc. The function of the converter at this end of the line is to convert these frequencies to the normal band of 0.2 to 11.6 kc and feed them to the telephone terminal equipment. At the other end of the line, the function of the converter is reversed. It passes the incoming frequencies of 0.2 to 11.6 kc directly to the terminal equipment but raises the frequencies to the outgoing currents from 20.8 to 32.2 kc. The Repeater CF-5 is used to increase the allowable length of the system. Furthermore, it provides for separate amplification of the transmission in each direction by separating them by a system of high and low pass-band filters and then amplifying each band separately.

The system will provide four circuits per pair, and the circuit may be operated at 6-db net loss for distances up to approximately 1,000 miles (with some relaxation of crosstalk standards if systems are operated for such great distances on adjacent pairs). The

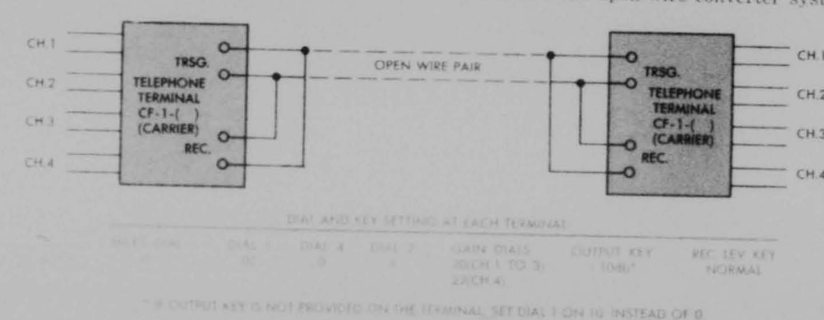

Figure 2-61 Pair-Per-System Operation of Telephone Terminals CF-1 ( )

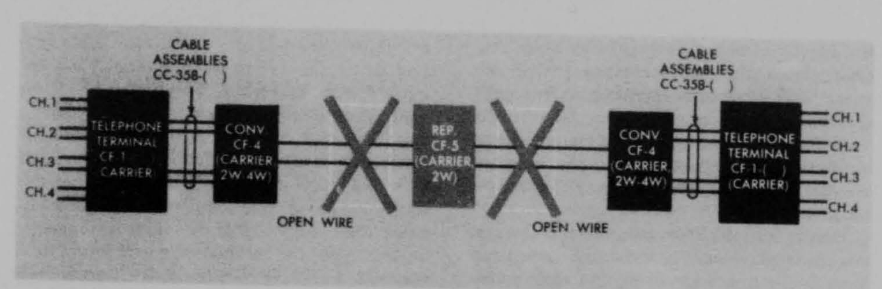

Figure 2-62 Open-Wire Converter Carrier System

normal repeater distance on 080 copper-steel is eighty to ninety miles. Noise and available gain limit repeater spacings. When used as a single section system without repeaters, distances up to 135 and 200 miles can be spanned with 080 copper-steel wire, for circuit net losses of 6 db and 30 db, respectively.

On four-pair and eight-pair open-wire lines, properly transposed, each pair may be used for an open-wire converter system. These will provide a maximum of thirty-two telephone channels on eight pairs of wires. This system may be used on the same pole line with fixed plant packaged carrier systems and on most foreign systems.

Combinations of the open-wire converter system on open wire in tandem with the spiral-four system can be operated without bringing the channels down to voice frequency at the junction point. Converter CF-4 and Repeater CF-3 are used at the junction in this case. Converter CF-4 may also be used alone at the junction of the open-wire line and the cable if the cable length does not exceed approximately one mile in length. This may be useful for camouflaging the approach to the carrier terminal, and it avoids the transmission penalties of having cable in the open-wire circuit. However, a source of power must be provided to operate the converter.

6. MULTICHANNEL VOICE-FREQUENCY CARRIER WIRE TELEGRAPHY

In general, carrier telegraphy uses an alternating current of fixed frequency for each channel, which is switched on and off at the sending end by a sending relay actuated by DC signals. Frequencies in the voice-frequency band are used for carrier telegraph systems. The carrier currents are transmitter through their respective channel filters, and at the receiving end are again separated by filters before being sent to the detector in order that the original may be reconstructed.

Circuits suitable for telephone transmission are used. However, since each telegraph channel uses only a small part of each voice-frequency channel, it is possible, therefore, to use more telegraph channels over the same voice-frequency band. Simultaneous operation of several (two to twelve) telegraph circuits may be obtained in the voice range, with each circuit being capable of duplex operation. (Simultaneous operation in each direction).

Carrier telegraph systems are operated on two-wire circuits, four-wire circuits, or the equivalent in which the transmission in the two directions is independent. In two-wire carrier telegraph operation, different frequencies are used for the two directions of transmission. In the case of four-wire, the same frequencies may be used in both directions. When using the same frequencies in this manner, the requirements as regards crosstalk between the two sides of the circuit are more severe for full-duplex telegraph operation than they are for telephone operation. Excessive crosstalk coupling between the two sides of the circuit will cause serious impairment of telegraph signals transmitted in one direction due to the telegraph currents being transmitted in the other direction.

Power levels used in carrier telegraph systems must be properly coordinated with telephone transmission levels. If the net loss from the originating long distance telephone switchboard to a point in the circuit is 0-db, this point is said to be at 0-db transmission level. The power in dbm (db referred to one milliwatt) per carrier telegraph channel, at a point of 0-db transmission level, is known as "specific level." Various particular adjustments of telephone and telegraph equipment gains or losses are made in order to realize proper telegraphic levels.

Carrier telegraph systems are available for operation on one or more of the four telephone channels of a spiral-four cable system using the Telephone Terminal CF-1 together with Telegraph Terminal CF-2. The latter may be used on any circuit employing the CF-1 equipment, both wire and radio. A schematic of a four-channel carrier telegraph terminal is shown in Figure 2-53. Telegraph on two-wire or four-wire basis is normally associated with other terminal equipment. In this case, the method of operation is designated two-wire or four-wire, depending upon whether the connection between the telephone terminal equipment and the tele-

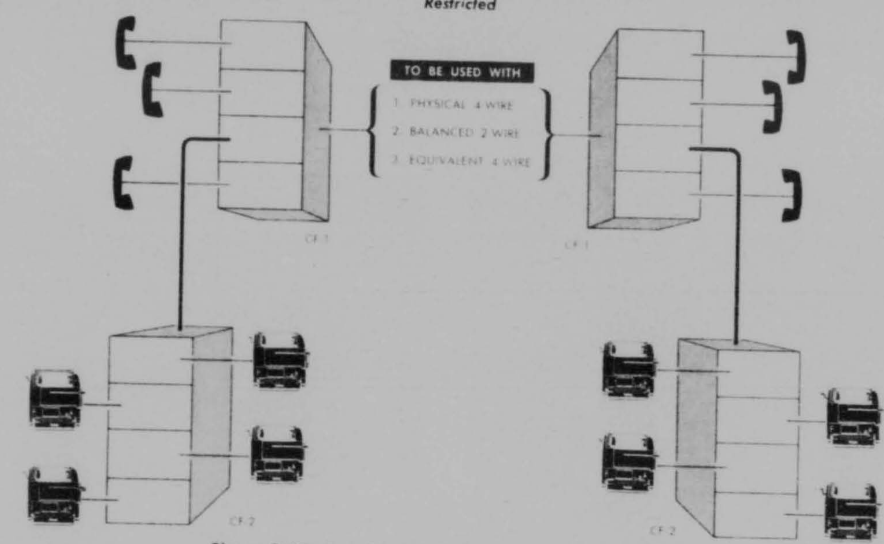

Figure 2-63 Capabilities of Carrier Terminal Equipment

graph terminal equipment is two or four wires. If a two-wire connection is used, four telegraph circuits can be obtained, using four frequencies for one direction of transmission and four different frequencies for the other direction of transmission. The addition of Telegraph Terminal CF-6 to this system will provide two additional telegraph circuits and make a total of six circuits available. If a four-wire connection is used between the telephone terminal and the telegraph terminal, the eight available telegraph frequencies, can be used to provide eight two-way telegraph circuits. In this case, the addition of the Telegraph Terminal CF-6 will increase the number of telegraph circuits to twelve.

7. SPEECH-PLUS-SIMPLEX AND SPEECH-PLUS-DUPLEX SYSTEMS

These systems are designed to derive carrier telegraph from a portion of the frequency band used by a telephone channel while retaining the use of the channel for speech. The speech-plus-simplex (S + SX) system, which is a British term, provides service in both direction on a circuit but in only one direction at a time. The speech-plus-duplex (S + DX) system is used both by the American and British forces. It provides full-duplex service (simultaneous operation in each direction) but may be operated half-duplex if required. The terms "half-duplex" and "simplex" are synonomous.

The British speech-plus-simplex equipment is built in three types: S + SX Nos. 1, 2, and 3. Nos. 1 and 2 are arranged to use carrier frequencies of 300, 900, and 2,300 cycles per second. No. 3 uses carrier frequencies of 300, 1,740, and 2,300 cycles per second. With any one of these three types of equipment, two telegraph circuits, together with one speech channel, may be obtained by using the 300 and 2,300 cycle channels for the telegraph circuits and the intervening frequencies for the telephone channel. One S + SX system normally uses either the 300 or 2,300 cycle frequency and uses the same frequency for both directions of transmission. Two such systems are therefore required to obtain two telegraph circuits from one speech channel. When adverse line conditions interfere with transfission, the telegraph is worked at one of the emergency frequencies of (900 or 1,740 cycles). In the S + SX equipment, the carrier is transmitted for spacing and interrupted for marking.

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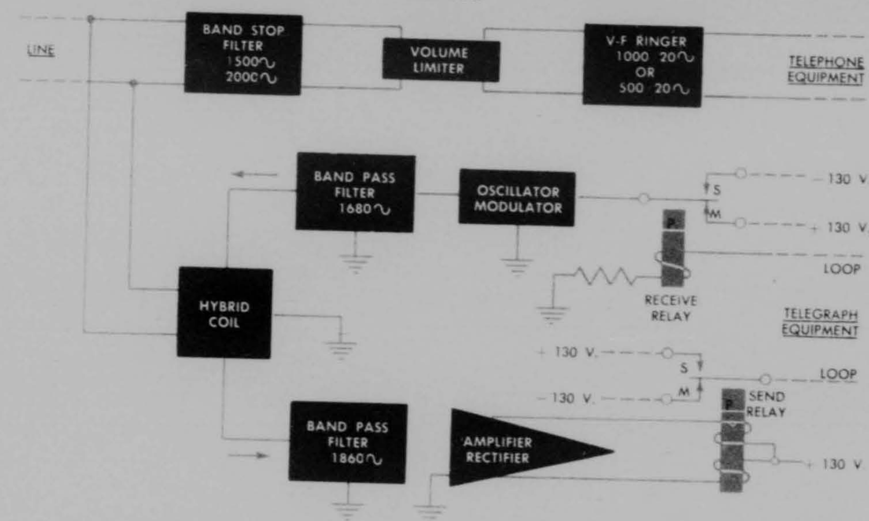

Figure 2-64 Block Diagram of Speech-plus-Duplex System

In the speech-plus-duplex (S + DX) system, a band from about 1,500 to 2,000 cycles is eliminated from the speech transmission circuit and used for telegraph purposes. The carrier midband frequencies employed are 1,680 cycles per second for one direction of transmission and 1,860 cycles per second for the other direction. Carrier is transmitted for marking and interrupted for spacing. The British equipment is known as British Apparatus, V.F., Telegraph S + DX. The American equipment, Telegraph Terminal TH-1 TTC-1, is shown in block diagram in Figure 2-64.

SECTION 6 - FACSIMILE

1. GENERAL

The reproduction of intelligence in its original form over great distances and in the most efficient manner possible is accomplished at present by using facsimile equipment operating over normal telephone or voice-frequency radio circuits. The intelligence to be transmitted or reproduced may be photographs, map photos, serial photos, weather maps, sketches, or mimeographed, printed, written, or drawn material.

The purpose of this section is to acquaint the student with the manner in which this is done, the basic principles of operation of facsimile equipment and its uses by the United States Air Force, to discuss the capabilities and limitations of military facsimile equipment, and to explain the installation and operation of facsimile equipment.

The problem of transmitting facsimile intelligence involves the photo-electric analysis of the subject matter at the transmitting station and then reproducing that matter in the proper relationship as to size, tone value, and position at the receiver end. This is accomplished by a mechanical-optical system combined with an electrical method of transmitting that which the optical system sees.

The **photo-electric tube** has often been called the electric eye, but unlike the human eye, it does not possess the ability to see several images at any one instant. The photo-electric tube, or cell, merely sees and measures the over-all light value reflected from the area it is made to look at, whether it is the outside landscape, the interior of a small room, or a minute spot on a piece of paper. In other words, the photo-electric tube cannot see a distinct picture, but sees a blur or monotone which contains the average light value of the entire picture.

Obviously it is not possible to show a picture to a photo-electric tube for an instant and expect the tube to analyse all the detail for subsequent transmission. It is first necessary to break the picture down into small areas containing monotone values of detail which the photo-electric tube is capable of analyzing correctly. It is for this purpose that minute portions of the picture are progressively scanned, the reflected light values measured, transmitted to the receiver, and assembled in their proper order.

2. PRINCIPLES OF OPERATION

General

The photo-electric analysis of the copy being transmitted is accomplished by a beam of light being projected from an exciter lamp onto a minute portion of the copy which is mounted on the drums of the sending transceiver. The transceiver is a combination transmitter and receiver. This beam of light is successively projected on to the copy as the drum moves axially, with each revolution, along the shaft in an amount equal to the area being scanned.

During operation, the drums of both transceivers rotate at constant and identical speeds. The drums are fed from right to left along the shafts upon which they rotate. These shafts are threaded with 96 threads to the inch, and the drums make 90 revolutions per minute, thus traveling 0.94 inches per minute. As the beam from the exciter lamp is focused on the copy mounted on the drum of the transmitting machine, it shines on successive elemental areas of the copy in lines around the circumference of the drum, always 1/96 of an inch to the right of the previous line. As the beam strikes various shades between black and white on the copy,

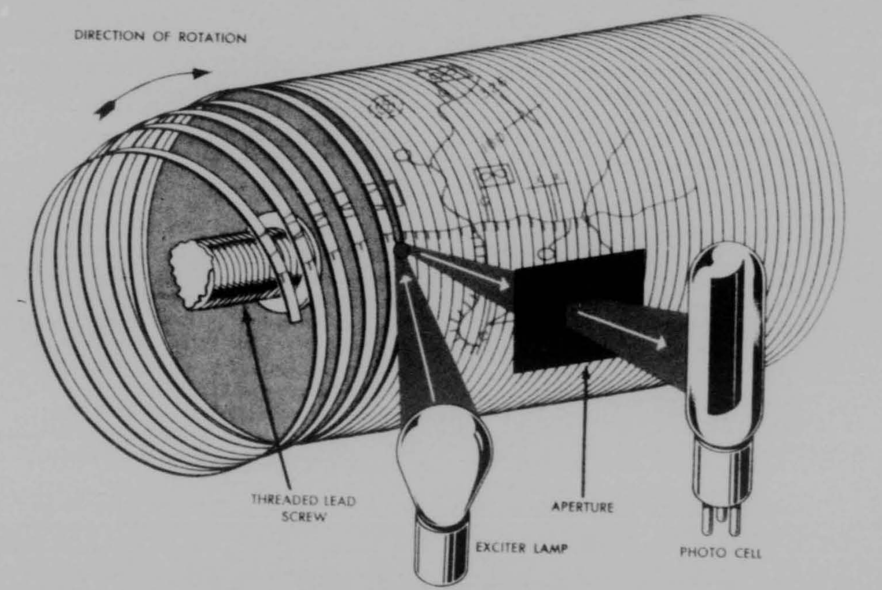

Figure 2-65 Principle of Facsimile Operation

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more light is reflected from the copy.

The photo-cell sees the reflected light from these successive elemental areas of the copy and translates what it sees into varying electrical impulses. The intensity of the electrical impulses depends entirely upon the intensity of the reflected light values. These impulses control the strength of a signal which travels over a regular voice channel (wire or radio) to the receiving transceiver, where the process is reversed, thus a complete reproduction is built up from the original copy.

Transmitting

In transmitting, a high-stability tuning-fork-controlled oscillator serves as the control for the entire unit. Energy from the oscillator is amplified and furnishes power for the synchronous motor which turns the shaft or lead screw upon which the drum rotates and moves from right to left. Energy from the oscillator is amplified in the power supply and furnishes a closely regulated voltage for the exciter lamp. Light from the exciter lamp is focused on a spot on the drum by a condenser lens. Light reflected from this spot focused on the copy is projected onto the photo-cell through a small aperture and lens system. The aperture limits the field of illumination scanned by the photo-cell to an area of about 1/100 of an inch square. Variations in light hitting the photo-cell control the amplitude-modulator upon which is impressed the carrier furnished by the fork oscillator unit. This carrier circuit passes through the voltage amplifier, gain control, power amplifier, and decibel meter, and is then sent out to the receiving equipment.

Receiving

In receiving, the fork oscillator unit in the transceiver performs the same functions as when transmitting. It controls the synchronous motor which turns the shaft turning the drum at the same constant speed as at the transmitting station. In other words, the drum turning the copy being transmitted and the drum turning the sensitized material at the receiving station are in exact synchronism. The process is in direct reversal for reception except that in photo printing a recording lamp is cut into the circuit to replace the electric eye. For direct contact recording, a stylus replaces the recording lamp.

Contrast

For successful operation, much attention must be paid to contrast. Contrast, the difference between black and white, is indicated by the maximum and minimum signal strength that may be obtained from the copy to be transmitted. Black or white may be made to give either the maximum or minimum signal strength desired. This depends upon the type of reproduction being made at the receiving station. Signal strength is measured in decibels and is indicated on the db meter. The correct contrast range is where the weakest signal received is just strong enough to record, and where the maximum signal will record as dark as is possible within the limitations of the recording method being used. For example, in the direct contact recording method, if the maximum signal is too great, the current flowing to the stylus will cause it to burn holes through the recording paper. Since the contract range varies with the different methods of recording, the receiving operator determines the contrast range to be established and the transmitting operator sets the range by making the proper readjustments at his station.

Phasing

Phasing is the last step before the actual transmission is begun. This is a short term for synchronization and probably is a more important step in the operation than establishing the correct contrast. The transmitting and receiving transceiver must be in perfect synchronization. They must be in step with one another. In other words, they must be phased. Failure to phase the equipment properly may result in the clamping bar on the transmitting machine appearing in the received copy as a blank space which would result in the received copy being cut in two; also one drum might commence turning before the other in which case an incomplete copy would result.

To phase properly, the transmitting operator, having obtained the contrast range

requested, disengages the drum-feed mechanism and moves the drum along the shaft, or lead screw, until the light beam strikes the white spot on the phase ring, and as the drum turns, a phase pulse is transmitted.

While the phase pulses are being transmitted, the receiving operator sets his drum in phase with that of the transmitter by setting his selector switch at the "record photo" designation. The phase button is then depressed completing a phasing circuit built in the transreceiver. This actuates the phasing magnet so that it stops the drum from turning until the phasing pulse is received from the transmitting machine. As the phase pulse is received, it actuates the magnet again, allowing the drums to turn in unison. This permits the same identical spots on both drums to pass the scanning points at the same instant. Care must be exercised not to touch either of the drums after they have been phased, or the process may have to be repeated.

As mentioned above, there are two methods of recording. The photographic method, and the direct recording method.

Photographic Recording

Photographic recording may be accomplished so that **positive** or **negative** copy is obtained.

In positive recording, black portions of the copy are translated into high-level signals which print at the receiving station as black. It naturally follows that white will print as white. When only one copy of high fidelity reproduction is desired, this method is used. This procedure requires photographic processing after the transmission is completed. It is important that the contrast range be established at 12-db's difference between black and white.

Negative recording is used when more than one copy of the transmission is required. Photographic processing is required to develop the negative, and extra copies are obtained in the same manner that prints are made from any photographic negative. Because of the reversal of black and white reproduction, black is translated as white and white as black. For this process, the contrast range is established at 8-db's difference.

Direct Recording

Direct recording gives the same black and white reproduction as the original. However, degree of detail and half-tone reproduction are sacrificed with this method of facsimile transmission as compared with positive transmissions. No further processing is required and here again, the contrast range must be established as 12-db's.

In this method, Teledeltos paper, a metallic coated paper, replaces the photo paper used in the other methods. The pressure of the stylus on the paper varies directly with the incoming signal.

3. FACSIMILE EQUIPMENT

Facsimile Equipment RC-120. This is a general purpose page machine sending a sheet of copy up to 7 x 8⅜" in about 7½ minutes. It is generally described in the preceding discussion. Facsimile Equipment RC-120-A and RC-120-B include minor improvements in design, but can be used interchangeably with Facsimile Equipment RC-120. A Converter CV-2/TX may be used with these models to permit transmission over radio-telephone channels.

Facsimile Set AN/TXC-1. In general appearance and technical features, this equipment is similar to the RC-120 models. This also is a general purpose page machine, sending a sheet of copy up to 12" x 10" in about twenty minutes. Converter CV-2/TX may also be used with the equipment. This equipment is not interchangeable with the RC-120 models.

Installation

In the installation of equipment in the field, several factors must be taken into consideration:

Operating Circuit. Great care will be exercised to insure that, should a telephone circuit be used, the circuit is free from crosstalk, is in itself electrically balanced, and free from outside operator interruption.

Power Requirements. For normal operation, any AC source furnishing 100 to 130 volts at 50 to 65 cycles will suffice. A source of supply should be readily available to furnish fully charged 6-volt storage batteries for emergency operation.

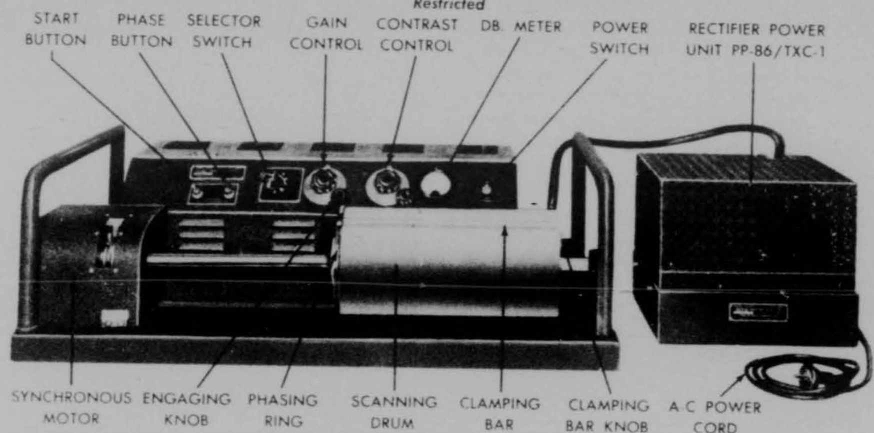

Figure 2-66 Facsimile Equipment AN/TXC-1

Space Factor. The operators must have adequate space in which to function. Normally, a fixed dark room is desirable for the necessary photographic activities. The portable dark room, a component of the equipment, can be made to suffice if required.

Noise Factor. Noise does not enter the picture as long as it is not electrical in nature so as to cause any induced unbalance of the circuit or equipment.

Light Factor. Light does not need special consideration since the operator requires only sufficient light to work comfortably. However, care must be exercised that sunlight or any other strong light is not permitted to shine directly on the copy to be transmitted.

Additional Items. If a volume of photographic transmissions is expected, a large table, sink, and running water also should be provided.

In choosing a location for setting up equipment, a flat solid surface within six to eight feet of the power source should be selected.

For AC operation, the power supply PE-140 will be used. This is a component of the equipment. This power supply stabilizes the power input to a constant level. For best results, it should be placed at the extreme right of the transceiver at the limit of the connecting cord. This is to prevent any power disturbance from entering the transceiver from the power supply.

For emergency DC operation, any fully charged 6-volt storage battery will furnish power for all transceiver models AN/TXC-1 RC-120-A, or RC-120-B. For the RC-120, a Power Equipment PE-150 is furnished and will be used.

For radio transmission, a converter CV-2/TX is used. In brief, this converter changes the signal from amplitude-modulated, such as is used for wire transmissions, to frequency-modulated for radio transmissions.

For successful operation of facsimile equipment, experienced facsimile operators (SSN 893) and facsimile technicians (SSN 894) are required to overcome the problems encountered in the routine installation, operation and maintenance of this equipment.

4. CAPABILITIES OF THE EQUIPMENT

As has been stated, facsimile offers the opportunity to transmit copy, from one area to another, in its original form. Facsimile will transmit photographs, map photos, aerial photos, weather maps, sketches, or any printed material which is written, or drawn. Perhaps the greatest use to be applied to facsimile in the Air Force is the transmission of weather maps and aerial photographs. An aerial photo could be taken, developed, and then transmitted to a headquarters hundreds of miles away in a matter of just a few hours for the whole procedure.

Should copy be too large for a single transmission, it can be broken in sections and each section transmitted separately and then reassembied in the proper order after the transmissions have been received.

It may be possible to photograph, enlarge or reduce the size of the copy to be transmitted. This would depend entirely upon the nature of the copy to be sent and on the amount of detail in the copy.

5. LIMITATIONS OF THE EQUIPMENT

Facsimile transmissions require a high-quality line, one which is balanced and free from noise and crosstalk. It is not advisable to attempt operation on a ground return circuit. Unlike teletype or similar equipment which can operate on any frequency on a very narrow band width, facsimile equipment requires the full voice frequency band for efficient operation. Facsimile, therefore, occupies the entire physical circuit for the entire frequency assigned. On the other hand, teletype will operate on a much poorer quality circuit, and, by the use of associated equipment, several channels can be established on one physical circuit.

Where facsimile is used to transmit plain text, it competes with teletype which can transmit at the rate of 60 words per minute on a tape for an indefinite period of time. Transmissions of 300 words per minute are possible on facsimile but, the time required to change sheets and to accomplish the photographic processing necessary makes it impracticable.

Transmission over radio channels is susceptible to interference from other radio channels, subject to fading and static. These interferences cause fading, distortion, and blurred impressions on the received copy.

The availability of trained technical personnel for the proper operation and maintenance of this equipment are factors limiting its use.

Facsimile is the best method for transmitting intelligence in its original form and in the fastest possible manner.

Facsimile requires a high-quality circuit and highly trained operating and maintenance personnel.

Facsimile cannot compare with other means of straight message transmission when ease of operation is considered.

Recent experiments have shown it possible to transmit by means of facsimile from ground to air. This was accomplished when a weather map was transmitted to a plane in the air.

As improvements are made in this equipment and as its capabilities are increased, it is felt that more widespread use will be possible.

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CHAPTER 3 - RADIO COMMUNICATIONS

SECTION 1 - GENERAL

1. USE

Radio, as a means of communication, satisfies to a high degree the principle of mobility. It is especially applicable to quickly changing situations in which wire communications are unable to keep up with the rapid movements.

Radiotelegraphy is the normal means of radio communication when the distances involved are great and when, by reason of the subject matter and the time factor, formal messages in cipher and code are required.

Radiotelephony is used when person-to-person communication is required in the interests of speed and necessity and when, by reason of the nature of the communication or the time factor involved, security is relatively unimportant.

The knowledge in the field of radio communications expanded greatly as a result of the pressure of necessity during World War II. There was little application of radio waves at frequencies above 100 megacycles prior to 1940. During the war, however, radio communication equipment was actually built and operated at 5,000 megacycles and radar equipment was constructed to operate at 30,000 megacycles. Radio and wire communications have been made increasingly complementary with advancements in equipment design. This has resulted in greater flexibility of communication systems and in greater use of telephony over both

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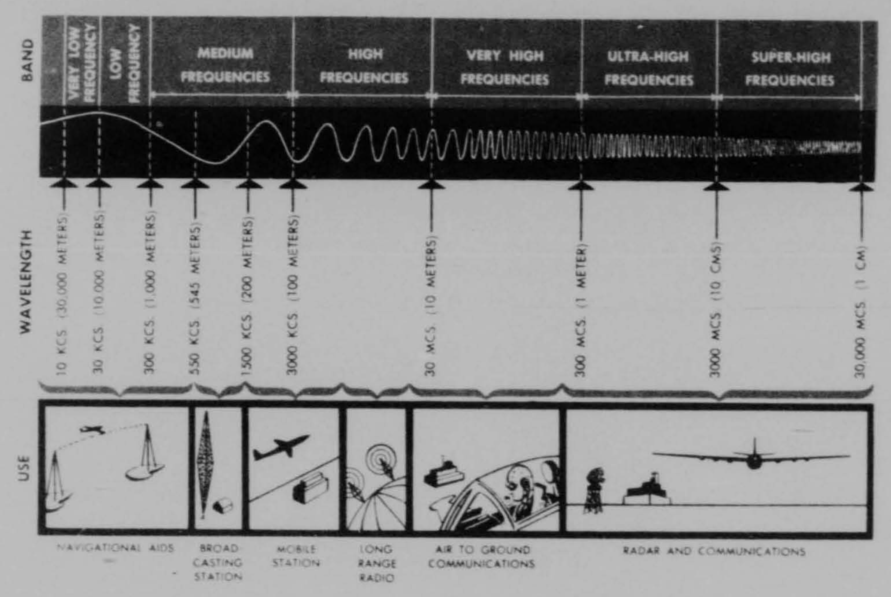

Figure 3-1 Radio Frequency Spectrum

media. This integration employing frequency modulation, pulse-time modulation, telephone and telegraph carrier, has resulted in economies in the use of the overcrowded frequency spectrum.

2. TYPES OF RADIO EQUIPMENT

Before examining the field of radio communications, it first is necessary to consider the types of radio equipment commonly used to meet USAF requirements.

The Joint Army-Navy nomenclature system classifies all radio sets according to the following types.

Airborne. A set installed and operated in an aircraft.

Air-Transportable. A set specially designed to be transportable by air, according to specification or military characteristics.

Ground, Fixed. A large set erected and operated at a permanent location, usually for long-distance communication.

Ground, General. A set which can be installed and operated for two or more types of ground use, that is, a set which can be used both as a vehicular ground set and a portable pack ground set.

Ground, Mobile. A set installed as an operating unit in a motor vehicle which vehicle has no function other than transporting the radio equipment.

Ground, Pack or Portable. A set capable of being carried by a man (or a horse) and operated, while stationary or in motion, by one person. This class includes those sets commonly known as "walkie-talkie" and "handy-talkie."

Ground, Transportable. A semiportable set, capable of being transported from place to place, but requiring a conveyance if moved for any considerable distance.

Ground, Vehicular. A set installed in a vehicle which is designed for functions other than carrying radio equipment, such as a set installed in a tank or armored car.

Shipboard. A set installed and operated from aboard a surface vessel.

General Utility. A set which can be used in two or more of the general type installations; airborne, shipboard, and ground.

3. RADIO FREQUENCY SPECTRUM

Military radio sets sometimes are further classified according to the frequency band in which they operate. Figure 3-1 shows the frequency spectrum as well as some of the uses of the various bands.

SECTION 2 - PRINCIPLES OF RADIO

1. GENERAL

In an electrical sense, the principles of radio are merely refinements of the basic principles that we learned in wire. The basic difference between these is that radio principles require the necessary devices permitting transmission between two points without physical connection.

The problem of transmitting intelligence in this manner is not a great one if we recall our electrical fundamentals. In the 1800's the German physicist, Hertz, discovered that an electrical spark would radiate energy. This was caused by the fact that the spark generated about it a magnetic field which, when induced into a second conductor, could produce a spark similar to the one generated although much weaker in amplitude.

Basically then, our problem in radio is to develop a device of somewhat the same nature as the spark and to modify it for the purpose of conveying intelligence.

Hertz's research proved that energy could be transferred through space with the earth's magnetic field the transporting medium. Thus it became the task of the radio pioneers to develop equipment which would generate alternating currents of a frequency high enough to permit efficient radiation. This frequency is known as radio frequency.

2. THE VACUUM TUBE

General

While working with the incandescent lamp in 1883, Thomas Edison noted that a black deposit appeared on the glass globes. In an attempt to eliminate this he placed a metal plate inside of the globe. While this did not remove or eliminate the black deposit, it inadvertently made a great contribution to the development of radio which was then still in its infancy. Edison noted that when he placed a meter between the filament and the plate, a small electric current was flowing in the circuit. At the time, Edison did not know why this current flowed and he merely noted this in his records.

Today, it is know why this current flows. When a filament is heated, streams of electrons are emitted. This is called the **Edison, or thermionic effect.** The fact that the electrons given off by the hot filament will collect on the plate, or anode, and will flow in the path of least resistance back to the filament, constitutes the basic principle used in the vacuum tube today.

Physical Characteristics

Vacuum tubes are categorized generally according to their physical characteristics and functions. Vacuum tubes are classified according to the number of elements contained within the glass or metal envelope.

Diode. The simplest tube is the diode. It is a two-element tube, containing an electron emitter called a cathode and an electron collector called an anode, or more commonly, the plate. This tube serves as a "valve" in a circuit, permitting current to flow only when the anode has a positive potential. Because it was first developed by a British scientist, Ambrose Fleming, the earliest diodes were known as "Fleming valves."

Triode. The diode did not fill all of the functions desired of a tube. True electron control did not exist until an American, Lee deForest, perfected the triode tube which added another element to the tube, called the "grid." By placing a high positive potential on the plate, the electron flow from the cathode could be controlled very easily by a small amount of negative voltage on

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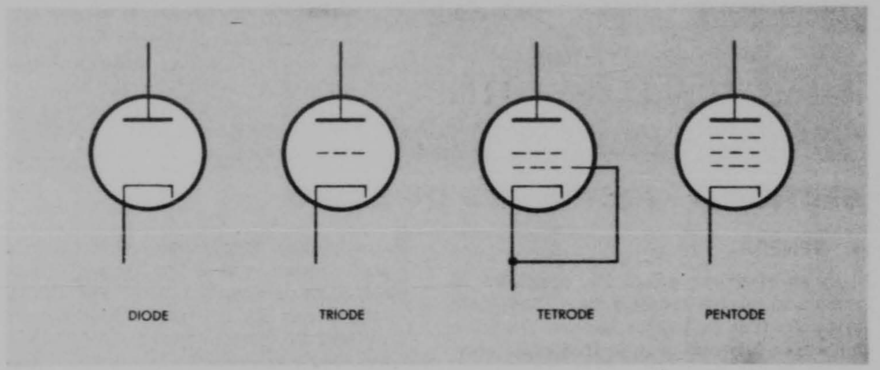


Figure 3-2 Physical Characteristics of Vacuum Tubes

the grid. The voltage impressed on this grid is more commonly known as "grid bias." Thus the triode can be used to vary and control a higher voltage and current in the anode circuit merely by a variation of a small amount of change in grid voltage.

Tetrode. The tetrode, or four element tube, had to be developed in order that the tube could be used to amplify signals at a high frequency. Because of the inter-electrode capacitance that exists in the triode between the plate and the grid, electron flow is impeded. The capacitive effect causes the tube to regenerate, that is, to feed back voltage into the grid circuit, causing oscillation. (Oscillation is considered later in this section.) The addition of another element, known as the **screen grid**, located between the control grid and the plate, reduces this feedback of voltage. A positive potential lower than that of the plate when impressed on the screen grid accomplishes this reduction.

Pentode. Some of the electrons on striking the anode bounce off and are attracted to the screen grid, causing current to flow in the screen grid circuit. Known as "secondary emissions," this reduces plate current flow. Consequently, another element known as the "suppressor grid" is placed between the screen grid and the plate. Since it is at the same potential as the cathode, it repels any electrons which bounce off the plate, but because of its construction, it permits the fast moving electrons emitted from the cathode to go directly to the plate with a minimum of retardation. The addition of this third grid produces a five-element tube called a pentode.

Beam Power Tube. The beam power tube, a form of tetrode, is also used in circuits where the secondary emission is reduced by designing the elements so that the electrons travel in sheets, rather than drifts. This high concentration of negative charge reduces the potential between plate and screen grid sufficiently to prevent the secondary emission.

Other Types. Other types of tubes are the photo-electric and cathode-ray tubes which are covered in detail elsewhere in this text.

Functions

Although the capabilities of vacuum tubes are being expanded more and more each day, below may be considered reasonably complete the possible uses of the tubes as described plete. These functions are:

Rectification: The ability of the vacuum tube to convert alternating currents to direct currents. This is a property possessed by all vacuum tubes since electron flow can only be in one direction, that is, from the negative source to the positive potential.

Amplification: The ability of the vacuum tube to control a large power or voltage with a small power or voltage. This is one of the most important uses of the vacuum tube.

Oscillation: The ability of the vacuum tube to generate high-frequency alternating currents. This is accomplished by permitting part of the tube output to "excite" itself and cause an alternating current to flow within the circuit.

Frequency conversion: The ability of the vacuum tube to receive different frequency inputs and to produce a totally different frequency output. By introducting various voltages of different frequencies to the elements, the resulting current flow can be a combination of or difference between the input frequencies.

Modulation: The ability of the tube to vary the frequency or amplitude of its output at an audio rate.

Detection: The ability of the tube to produce a current flow from a modulated wave which will conform to the original signal used to modulate the wave.

Other uses include the conversion of light energy to electrical energy, and vice versa. The former is accomplished by the photo-electric cell and the latter by the cathode-ray tube.

This consideration of the vacuum tube, brief as it is, should be sufficient to produce understanding of the general considerations of radio transmission and reception.

3. RADIO FREQUENCY GENERATION

Before transmission of intelligence by radio methods can be made, it is necessary to develop a carrier wave of radio frequency. The device that generates this carrier wave is known as an oscillator.

The Simple Oscillator

A simple oscillator circuit is shown in Figure 3-3. Assuming that switch S can be thrown to either position, when it is thrown left it connects capacitor C across the battery. Electrons will flow from the top plate to the bottom plate of the capacitor making the bottom plate negative. If the switch is then thrown to the right, the extra electrons which have gathered on the bottom plate will return to the top plate through inductor L thus creating a flow of current and a magnetic field around L. This action equalizes the electron charge which stops electron flow in the circuit. The magnetic field in collapsing induces a voltage across L due to self-induction. This new voltage aids the electron flow to the top plate and thereby causes more electrons to pile up on the upper plate. Current will then flow in the opposite direction, that is, from the top plate to the

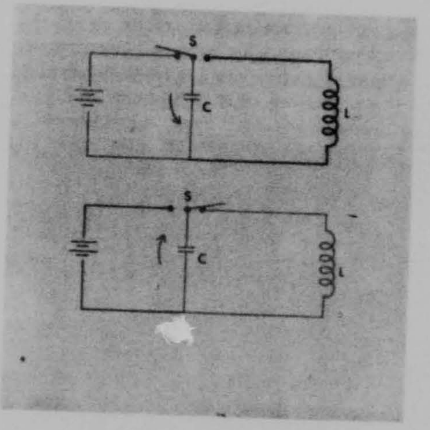


Figure 3-3 Simple Oscillator

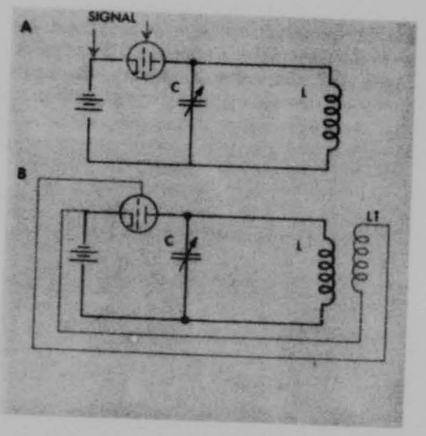


Figure 3-4 Simple Vacuum Tube Oscillator

bottom plate. Soon the bottom plate has an excess of electrons and current flow starts in the opposite direction. The rate at which this current will oscillate back and forth, or its frequency, will be determined by the values of L and C. The larger the values of L and C, the longer the time needed to charge C. This results in a low frequency.

Were it not for the resistance of the circuit these oscillations would continue indefinitely. However, the circuit resistance causes each succeeding oscillation to be of lesser amplitude with the result that eventually there is no current flow. In order to have further oscillation, it is necessary to turn the switch to the left to charge the capacitor and then to the right to start the chain of events again.

The frequency relationship is:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

In our simple oscillator, we are faced with two problems: first, to overcome the circuit resistance and prevent damped oscillations or oscillations of decreasing value; the second, to supply new voltage to the circuit whenever the need arises.

The circuit resistance can be overcome by increasing the voltage through the circuit. (See Figure 3-4). In this circuit, a triode tube has been placed. The oscillation radio frequency in the coil-capacitor circuit causes a radio frequency voltage to be placed on the grid of the tube. Condensor C1 provides a path for the radio frequency. Resistor R serves to provide a bias for the grid and at the same time to provide a path for excess electrons which might pile up on the grid. The output of this tube is amplified. In order to sustain oscillations, it is necessary to return part of this output to the grid circuit. This is known as "feedback." By placing a coil in the plate circuit adjacent to the grid coil (see Figure 3-5), voltage is induced in the grid circuit from the plate circuit.

As discussed later in this section, certain tubes amplify in a different manner depending upon the method of putting voltage on the grid. In this oscillator (if the tube is so constructed that the electron flow is very great when no voltage is on the grid), the tube will start itself, for at the time the circuit is closed, electron flow must be established immediately before oscillation can be realized. It is apparent that the characteristics of the tube determine the oscillatory value of the circuit; if in any way the tube loses its amplification qualities the oscillations will not take place. It is imperative that the time consumed by the electrons in traveling from cathode to plate be considered when very-high and ultra-high frequencies are employed for the phase relationships within the tube itself are of such a nature that the effective power output of the tube is greatly reduced. In the triode oscillator then, it must be remembered that generally, high-powered tubes operate on low frequencies. An increase in the frequency of the circuit results in a lowering of power output.

The vacuum tube oscillator mentioned here is the tickler-coil type. While not used generally today, it illustrates the vacuum tube type of oscillation. Other types of oscillators are as follows:

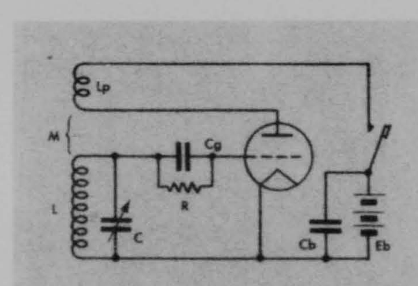


Figure 3-5 Tickler Coil Oscillator

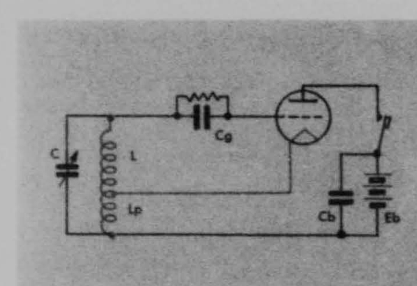


Figure 3-6 Hartley Oscillator

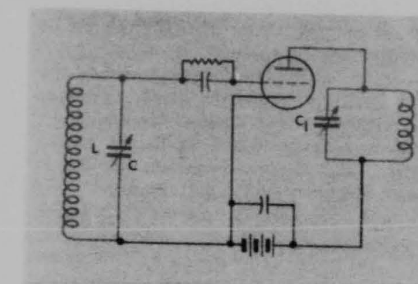


Figure 3-7 Tuned-Plate, Tuned-Grid Oscillator

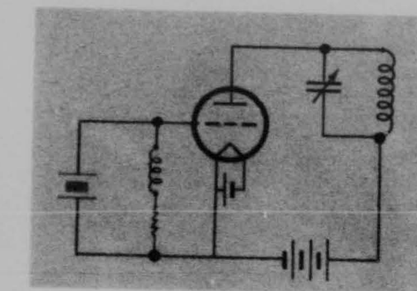


Figure 3-8 Crystal Oscillator

Hartley Oscillator. All oscillators are divided generally into types depending upon the method of feedback. The tickler-coil type accomplishes its replenishing of the circuit power by induction between the plate and grid coils. This method is widely used.

Another application of the induction method is found in the Hartley oscillator. It is to be noted (see Figure 3-6) that coil L in this case is two coils in one. The whole coil comprises the inductor part of the tank circuit while the bottom part is the feedback element, corresponding to the plate coil in the tickler-coil type. The values of L and C determine the frequency of the output signal. The key in this oscillator, as in all oscillators, is the manner of exciting the grid. In this oscillator, the grid receives its voltage through induction from coil L.

Tuned-Plate, Tuned-Grid Oscillator. Another type of oscillator depends upon the capacitance between the grid and the plate of the tube to couple the feedback to the tuned circuit. In Figure 3-7, an oscillator called the "tuned-plate, tuned-grid oscillator" is shown. There is an inherent capacitive effect in the triode tube which normally is reduced with a screen grid, however, at times the capacitance is utilized. This oscillator is a case in which the tube is so used. Here, the frequency of the circuit is established by the equal products of the L and C of the grid circuit and L_1 and C_1 of the plate circuit. The plate circuit is tuned to resonance; that is, it has the same frequency as the grid circuit. Coupling between the two is accomplished by the capacitive effect of the tube electrodes. In cases where the operating frequency of the oscillator is low, it is necessary to install a capacitor between the grid and the plate. Remembering that the capacity of the condenser is such that small capacitors work with high frequencies, it is apparent that lower frequency oscillations could not be accomplished with the tube capacitance alone because of the small size of the electrodes themselves.

Crystal Oscillator. Certain minerals possess the ability to convert mechanical stress into voltage values and conversely to produce mechanical motion when voltages are applied to them. In quartz, for instance, a mechanical stress applied to the crystal produces a dielectric stress between its outer surfaces. Application of electrical energy to the crystal produces a mechanical strain. This strain produces a dielectric stress or voltage across its face, producing a strain which in turn produces another voltage. The frequency of this action is determined by the thickness of the crystal. The mechanical and electrical actions of the crystal are self sustaining as long as there is an initial voltage potential established in the circuit.

This phenomenon permits the crystal to be used as an oscillator since it produces an alternating current of radio frequency. It serves as the oscillatory medium as well as the resonant circuit. In this case, feedback is accomplished in the tube itself, but the crystal serves to establish a frequency which will not vary as much as one set up with the conventional coil and condensor.

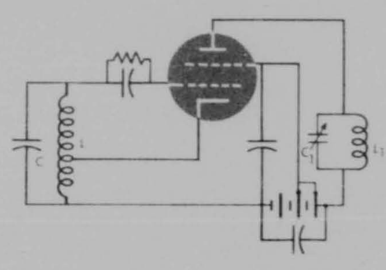


Figure 3-9 Electron-Coupled Oscillator

Electron-coupled Oscillator. Another oscillator using the tetrode likewise provides frequency stability. Oscillators by themselves are of no value unless they are coupled to a load or resistance. Just as an electric motor will slow down when a load is applied, so will an oscillator suffer frequency distortion when a load is applied unless proper coupling and shielding are employed.

In the electron-coupled oscillator, we have a combination oscillator and amplifier. The screen grid of the tetrode acts as a plate and with the cathode and grid acts as a triode. This "triode" serves as an oscillator. Electron flow within the tube varies according to the oscillations established by the resonant circuit. The tube output in the plate circuit is unimpeded. The structure of the screen grid is such that electron flow is controlled at a rate determined by the oscillatory action that takes place in the triode section of the tube.

Since the output is taken off across the tuned circuit (C_1 and L_1) coupling takes place within the tube itself. Since the screen grid serves to shield the oscillatory circuit from the load circuit, frequency stability is good in electron-coupled oscillators.

4. AMPLIFICATION

General

It has been stated previously that the outstanding ability of the vacuum tube is amplification. This term (amplification) is misused in a sense, for the vacuum tube does not take a small voltage and make it a larger one, but, instead, controls a high potential and current with a very small voltage impressed on the grid. The use of the term "valve" instead of amplifier would be more correct.

Since the grid voltage is a key factor in determining the amplification value of a tube, amplification types are categorized according to the method of biasing the grid. To illustrate the relationship between grid voltage, or bias, and plate current, graphs are used, showing the characteristic curve of the tube in question. The point along this curve at which the grid is biased, generally determines the class of amplification. These classes of amplification follow.

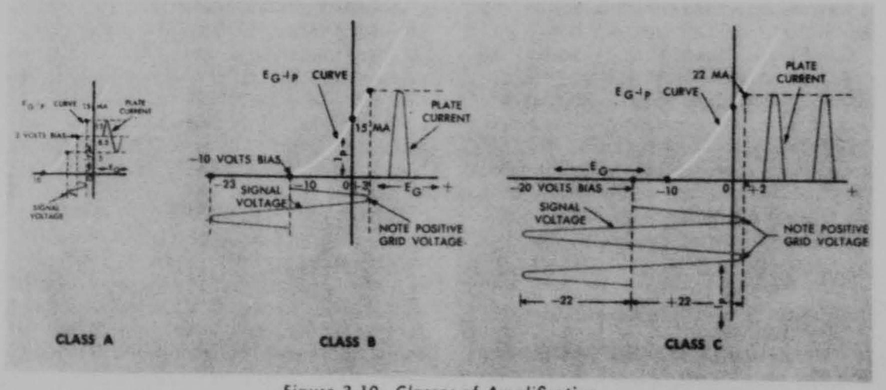


Figure 3-10 Classes of Amplification

Class A Amplifiers

All amplifiers which operate on the straight or linear portion of the plate current-grid voltage curve are known as "class A" amplifiers. These will give voltage amplification with high fidelity, that is, the input signal and the output signal are identical. The efficiency of this tube is low in that it draws plate current at all times. This amplifier is used extensively in those cases where fidelity of signal is paramount. It is occasionally used as a power amplifier.

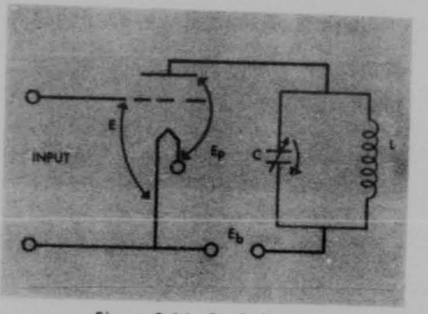


Figure 3-11 Tank Circuit

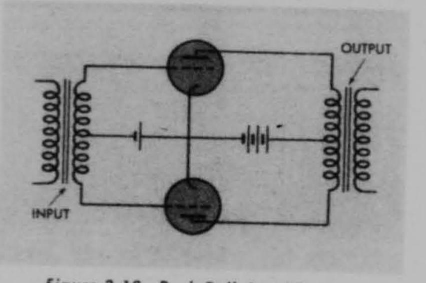


Figure 3-12 Push-Pull Amplification

Class B Amplifiers

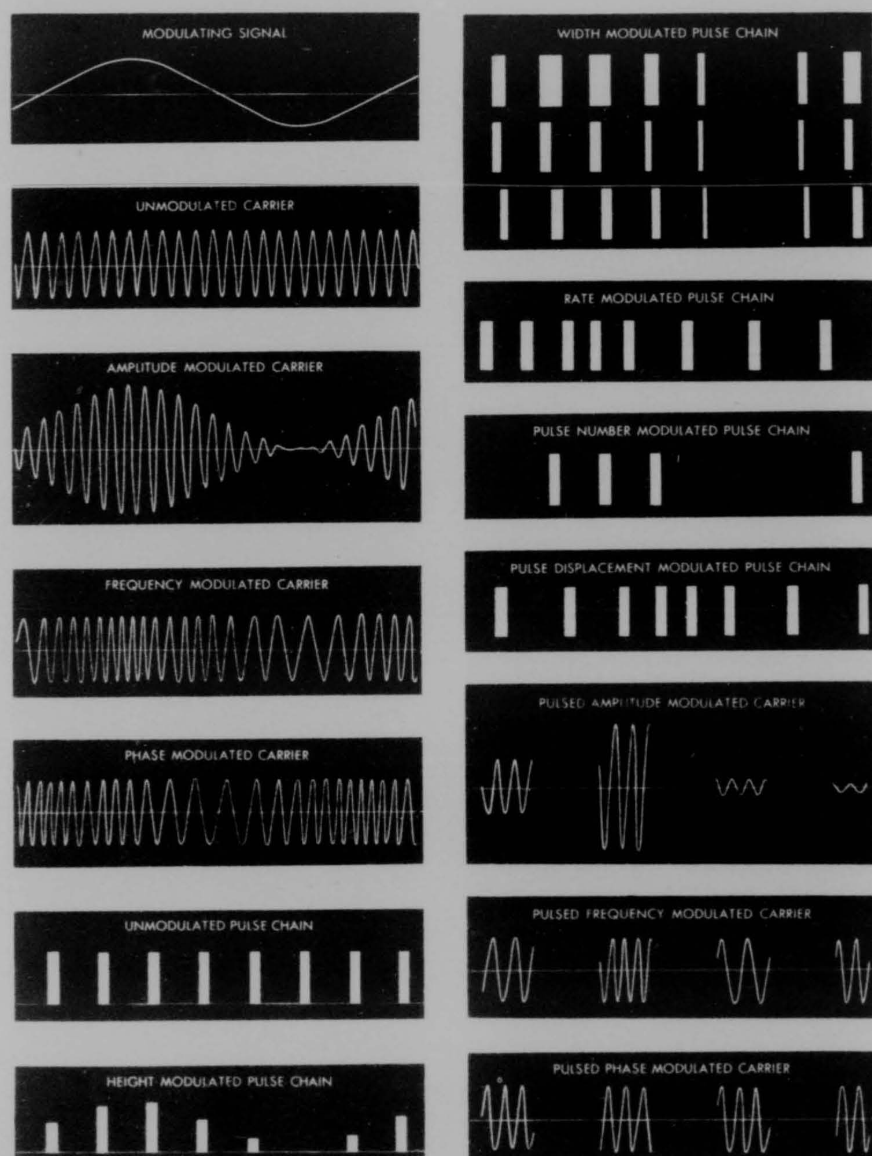
All amplifiers which operate on the lower portion of the characteristic curve of the tube are known as "class B" amplifiers. The grid is biased so that plate current flows only during the times when the grid or signal voltage is positive. The point at which the grid stops current flow in the plate circuit is known as the cutoff point. Class B amplifiers operate at cutoff permitting high efficiency to be realized since the plate is drawing current only half the time. Because of the fact that the plate current flows only half the time, the output signal is not symmetrical with the input signal. In radio transmitters, the class B amplifier can be used provided an oscillatory or tank circuit is used. (See Figure 3-11.) In this case, when the period in which the positive signal peaks are impressed on the grid, the potential across the filament and the plate causes a voltage to be applied to the tank circuit LC since it parallels the filament and plate. As soon as the positive peak of the plate current falls off, the condensor discharges through L (as shown by the arrow) and charges the other plate of the condensor. During this period no plate current is flowing as the input grid current is negative. Because of the electrical inertia of the charge built up in the tank circuit, current will flow in an opposite direction, completing the cutoff cycle. This is known as the "flywheel" effect. Thus the class B amplifier can be used in transmitting circuits without a loss of signal fidelity. Since the flywheel action supplies this necessary correction of the wave shape, class B amplifiers cannot be used in receiver circuits since the tank circuit is not employed. However, by using two tubes in parallel, the flow of current will be constant. So, in receiver systems, class B amplifiers can be used only in tandem or push-pull. (See Figure 3-12.)

Class C Amplifiers

All amplifiers which operate below the cutoff point are known as class "C" amplifiers. These amplifiers operate only on the high positive peaks of the grid potential. (See Figure 3-10.) Class C amplifiers are used only in transmitters having very high power efficiency but low power amplification, because the plate current flows but a small portion of the time.

5. MODULATION

Radio frequency waves are capable of carrying intelligence provided some method is employed to impress the intelligence upon the wave. The method is known as modulation. Discussion in this text will be limited to amplitude modulation (AM), frequency



modulation (FM), and pulse-time modulation since these are the principal types employed by the USAF. Modulation has been defined as the "process of producing a wave, some characteristics of which vary as a function of the instantaneous value of another wave, called the modulating wave."

Probably one of the most familiar cases of modulation is that of the carbon granule microphone employed in the telephone. The pressure of the sound waves against the diaphragm causes the resistance of the carbon granules to vary with time.

Amplitude Modulation

Amplitude modulation may be defined as the variation of the strength of the RF output of a transmitter at an audio rate (Figure 3-13). The RF energy has to increase and decrease in power according to the audio frequencies. If the audio frequency is high, the radio frequency must vary in amplitude mere rapidly than if the audio frequency were low. If the audio note is loud in volume, the radio frequency energy must increase and decrease by a larger percentage than if the audio note were soft. Thus, the RF variations must correspond in every respect with the audio frequency (AF) variations.

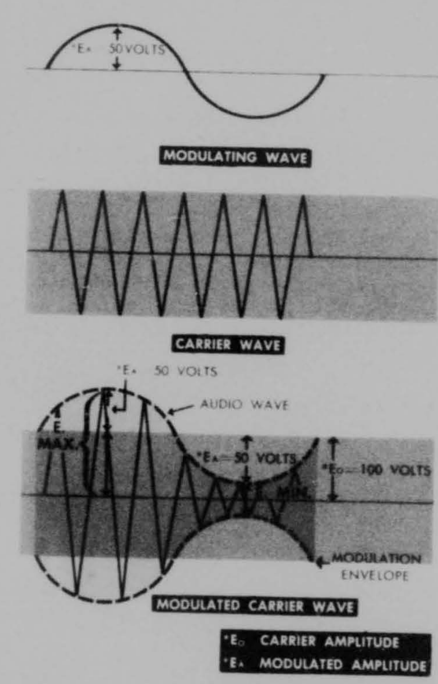


Figure 3-13 Amplitude Modulation

Carrier Requirements. The carrier frequency is the radio frequency upon which the modulating signal is impressed. For proper amplitude modulation, the carrier should be completely free from inherent amplitude variations such as might be caused by insufficient filtering of the power supplies and should be a pure sine wave of the desired frequency. Furthermore, it is essential that the carrier frequency be entirely unaffected by the application of the modulation frequency. In other words, the frequency of the carrier wave must not change when a modulating wave is applied.

Percentage of Modulation. The degree of modulation is expressed by the percentage of maximum amplitude deviation from the normal value of RF carrier. The effect of a modulated wave, as measured by receiver response, is proportional to the degree of percentage of modulation.

The percentage of variation of the total voltage of the final RF amplifier stage will depend upon the ratio of AF to the DC voltage. For example, if the DC plate voltage of the RF amplifier is 100 volts and the AF voltage is 50 volts, the two voltages will add (when they are of the same polarity) to give 150 volts. They will subtract (when they are of opposite polarity) to give 50 volts (Figure 3-13). The plate voltage of the RF amplifier will vary between 50 and 150 volts. Since the variation (50 volts on either side of the DC voltage) is one-half of the DC voltage of 100 volts, the transmitter is said to be modulated 50 per cent. The mathematical expression for degree of modulation is:

$$m = \frac{E_{max} - E_o}{E_o} \times 100 \text{ or } \frac{E_o - E_{min}}{E_o} \times 100$$

where m = per cent of modulation

E_o = Carrier Amplitude.

Thus percentage or degree of modulation may be defined as the percentage of variation of the modulated wave compared with the unmodulated wave.

It is important that the amplitude of the carrier wave be varied as much as possible because the output of a detector in a radio receiver varies with the amplitude variations of the received signal. This is why a comparatively low power station, well modulated, will often produce a stronger signal at a given point than a more powerful, but poorly modulated station located the same distance from the receiver. However, the maximum limit of modulation is 100 per cent.

Power in the Modulated Wave. Since power varies with the square of either the current or voltage (if the value of the resistance in the circuit remains constant), the instantaneous peak power of a 100 per cent modulated wave is four times that of the unmodulated carrier power. With a sine wave modulating signal, the average power of a 100 per cent modulated carrier wave is one and one-half times the unmodulated carrier power; that is, the power output of the transmitter increases 50 per cent with 100 per cent modulation.

Linearity. The amplitude of the carrier should follow faithfully the amplitude variations of the modulating signal up to the limit of 100 per cent modulation. When the modulated RF amplifier is incapable of quadrupling its power output at the peak of 100 per cent, modulation will cause distortion of the modulation envelope. A graph showing the relationship between the RF amplitude and the instantaneous modulating voltage is called the modulation characteristics. This graph should be a straight line between the limits of zero and twice the carrier amplitude. Curvature of the line between these limits indicates nonlinearity in the amplifier.

Modulation Capability. The modulation capability of a transmitter is the maximum percentage of modulation possible without objectionable distortion due to nonlinearity. The modulation capability should be as high as possible so that the most effective signal can be transmitted for a given carrier power. The maximum modulation capability is 100 per cent.

Over modulation. The carrier wave should never be modulated over 100 percent since this produces undesirable distortion in the transmitted signal. In the case of over 100 per cent modulation, the peak amplitude exceeds twice that of the carrier wave. This demands that the RF amplifier be capable of supplying more than four times the normal carrier power at rest and then will be completely shut off for other periods of time. The result is the appearance of the harmonics in the modulating signal.

Sidebands. (Figure 3-14). The modulated wave is a combination of several frequencies. A mathematical analysis is required in order to determine the frequencies present in the wave. As a practical example, if the RF carrier is 100 kilocycles and the audio frequency is 1,000 cycles or 1 kilocycle, the wave will contain the following frequencies:

Fundamental frequencies:	100 kc—1 kc
Second harmonic:	200 kc—2 kc
Sum frequency:	101 kc
Difference frequency:	99 kc

Harmonics other than the second are produced, but they are weak and easily dispensed. All these frequencies are present in the plate circuit of the final RF amplifier. The plate circuit is broadly tuned to 100 kilocycles so that only frequencies of 99, 100 and 101 kilocycles will be transferred to the antenna through the antenna coupling circuit. The remaining frequencies, such as the second and third harmonics, will be bypassed. Thus, instead of transmitting only one frequency, the antenna is transmitting three frequencies very close together.

These additional frequencies are known as "sideband frequencies," or "sidebands." These sidebands are separated from the carrier frequency by the amount of the audio

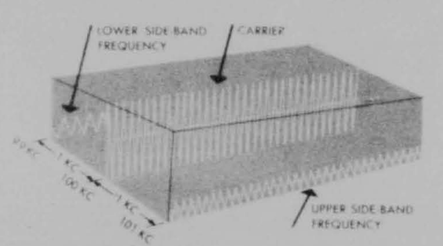


Figure 3-14 Carrier Wave and Side-Band Frequencies

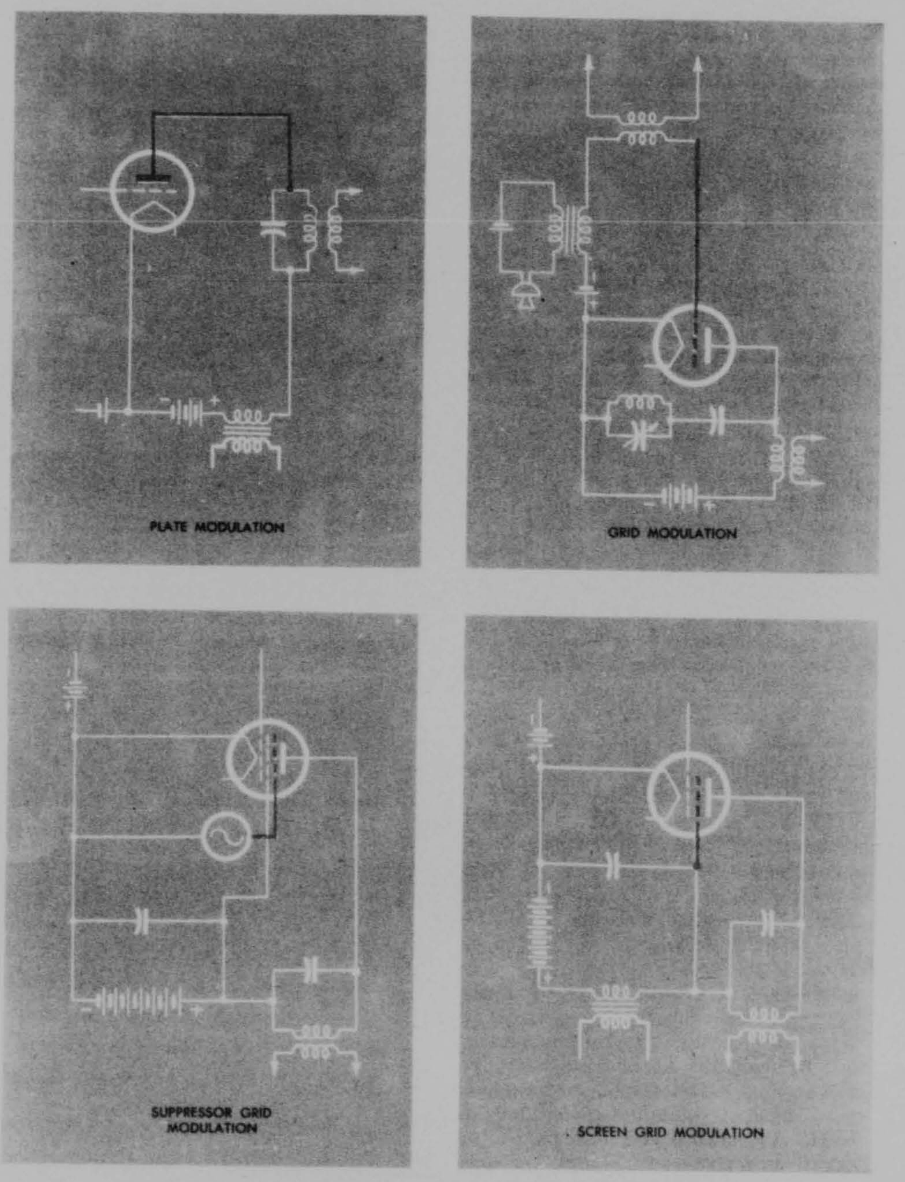


Figure 3-15 Methods of Amplitude Modulation

frequency. Thus, if the audio frequency had been 2 kc, the sidebands would have been 98 and 102 kilocycles. The higher the audio frequency the farther both sidebands will be from the carrier.

In actual speech, many audio frequencies are used to modulate the carrier wave. There will be a pair of frequencies (one upper and one lower) for each frequency present in the speech. The speech modulation will be made up of an entire band or group of frequencies.

The RF carrier varies in appearance only when it is being modulated. With zero modulation there are no sidebands. The additional power in a modulated carrier wave is supplied by the modulator and appears in the sidebands.

Methods of Amplitude Modulation. (Figure 3-15) There are various methods of amplitude modulation. The most common one is known as "plate modulation". In this method the AF modulating voltage is applied to the plate of the RF amplifier and causes the carrier output to vary in accordance with the audio frequency. Application of the AF voltage to the control grid of the RF amplifier is known as grid modulation or grid-bias modulation. Suppressor grid modulation is obtained by applying the audio frequency to the suppressor grid of a pentode power amplifier. Screen grid modulation may be accomplished by the use of a tetrode. Cathode modulation, in which the audio frequency is applied to the cathode circuit, is a combination of plate and grid modulation.

Plate modulation of the final RF stage of a radiotelephone transmitter is known as high-level modulation, since the modulation takes place at the highest power level of the system. If the modulation takes place in an intermediate stage with one or more high power amplifiers following, it is known as "low-level modulation." In low-level modulation, RF amplifiers which follow the modulated stage are operated as linear amplifiers, that is, their AC output voltage faithfully reproduce the applied grid voltages without distortion. In high-level modulation, the final RF power amplifier is always operated as a class C amplifier.

Frequency Modulation

Frequency modulation may be defined as "the variation of the frequency of the RF output of a transmitter by an audio signal" (Figure 3-16). The unmodulated frequency is called the "rest frequency." When a carrier wave is frequency modulated, the strength of the carrier wave is not varied but its frequency is changed or shifted from its rest frequency. This shift, known as "deviation," is proportional to the strength of the modulating signals. The rate at which the carrier frequency is varied is determined by the frequency of the modulating signal. The changes in frequency of the transmitter takes place within certain specified limits in accordance with the intelligence to be transmitted.

In military practice, the maximum deviation allowed for any channel is 40 kilocycles. This means that the strongest audio signal which can be used is limited to that value which will cause a maximum deviation of 40 kilocycles either side of the resting frequency. Weaker signals will vary the frequency by an amount less than 40 kilocycles. A total of 80 kilocycles, known as the "carrier swing," is available to each station for

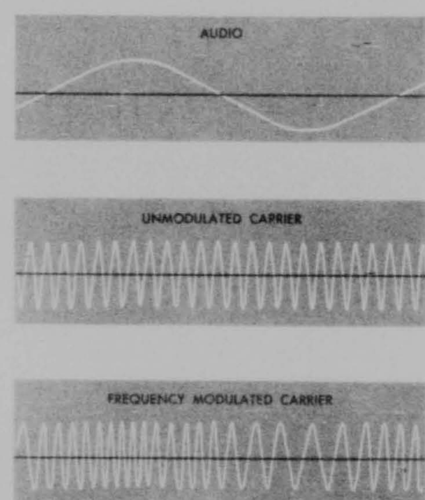


Figure 3-16 Frequency Modulation

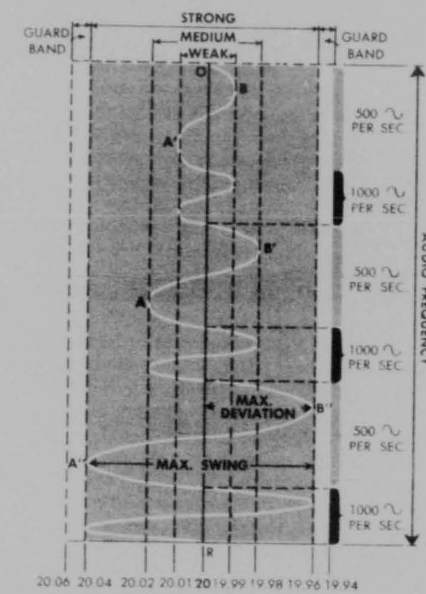


Figure 3-17 Graphic Review of Principles of Frequency Modulation

frequency variation during transmission. A band of 20 kilocycles is allowed for separation purposes between channels. This is known as the "guard band." Thus, the channel allotted to each station consists of two deviation ranges of 40 kilocycles each, plus half the guard band on either side, or a total of 100 kilocycles.

Linearity. A transmitter in which frequency deviation is directly proportional to the amplitude of the modulating signal is said to be "linear." It is essential also that the carrier amplitude remain constant under modulation, which in turn requires that the transmitter tuned circuits, as well as the antenna, have a broad enough response to handle audio frequencies without discrimination on the entire range transmitted. Normally, this requirement is easily met.

Sidebands. A circuit which is designed to produce a frequency modulated deviation of 40 kilocycles, may produce signals differing from the rest frequency by much greater amounts than the deviation. This is because in addition to the normal sidebands existing in amplitude modulated circuits, other sidebands differing from the rest frequency by multiples of 2, 3, 4, etc., of the modulation frequency exist. The spread of these frequencies becomes greater when the high modulation frequencies required in carrier telephone transmissions are considered. This characteristic is inherent in the circuit. The strength of the emissions on frequencies beyond the normal deviation, in general, do not decrease in strength in a manner directly proportional to the separation from the rest frequency. In some cases the strength of these emissions on a frequency greatly different from the rest frequency may be considerably stronger than the emissions on a frequency reasonably close to the frequency of maximum deviation. The mathematical solution of these emissions is beyond the scope of this text. These sideband frequencies may cause interference on other radio channels which are considerably removed in frequency from that of the offending transmitter. This is especially true if an excessively large modulation index is employed.

The modulation index may be likened to the percentage of modulation which is applied to amplitude modulated signals even though it is quite different in character. For the purposes of this text, it will be defined as the "ratio of the deviation, in relation to the frequency of the modulating signal." Figure 3-18 illustrates the signal strength that may exist on the various frequencies for several modulation indexes. It is apparent that the interference caused by a frequency-modulated transmitter on channels considerably different from its primary channel of transmission may be considerably reduced by a good choice of the range of modulation indexes which are to be employed in the transmitter. Regardless of this choice, however, the transmitter will not be free of higher order side frequency radiations. The following notes pertain to Figure 3-18.

Modulation frequency .... 10 kcs
Design deviation .... 40 kcs

Under these conditions side currents of still higher order exist but their intensities

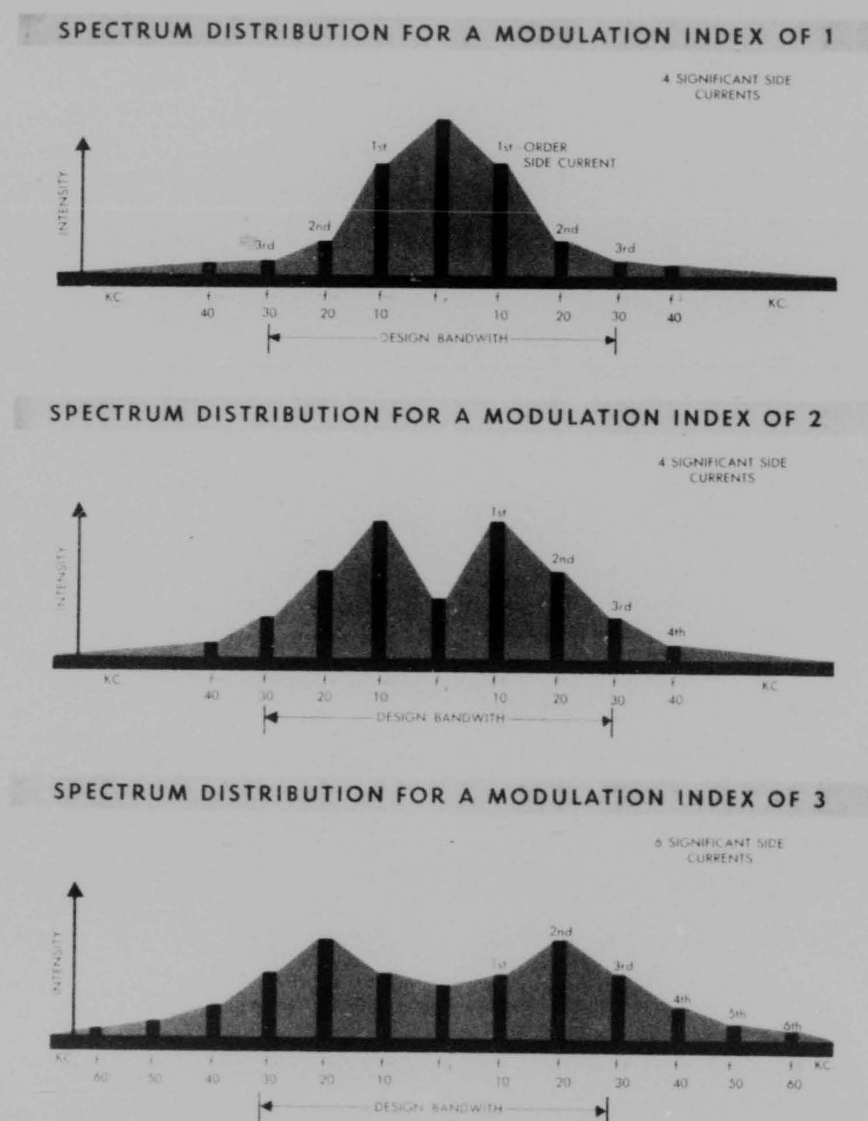


Figure 3-18 Spectrum Distribution for Modulation Indices

are too small to make a graphic comparison possible. However, these additional currents may cause transmitter-to-receiver interference when they are in close proximity.

When two or more modulation frequencies are employed (as is true, in general), additional side currents exist. Some of these currents have frequencies different from the rest frequency by greater amounts than those indicated.

Reactance-tube and Phase Modulation. A successful FM transmitter must fulfill two important requirements. The frequency deviation must be symmetrical about a fixed frequency, and the deviation must be directly proportional to the amplitude of the modulation and independent of the modulation frequency. See Figure 3-18. There are several methods of frequency modulation which fulfill these requirements. The two important types of frequency modulation used in military FM radio equipment are known as the "reactance-tube modulating system" and the "Armstrong phase-modulating system." The main difference between these two systems is that in the reactance-tube modulation method the RF wave is modulated at its source (the oscillator), while in phase modulation the RF wave is modulated in some stage following the oscillator. The results of these two systems are the same; that is, the FM wave created by either system can be received by the same receiver. The reactance-tube modulation system cannot be crystal-controlled as can the Armstrong phase-modulation system.

When it is desired to operate a transmitter with crystal control in frequency-modulation systems, it must be remembered that we will be operating in the very-high-frequency band, or higher. The oscillator in these units must be capable of delivering a signal of sufficient strength to excite the amplifiers used in the output stages. These high powers are injurious to crystals of the size required for very-high-frequency operation. Consequently crystals of the proper size can be used only if a small power output is required. For this reason, when large power output is required and high frequencies are used with crystal control, it is necessary to use thicker crystals which operate at lower frequencies. The output frequency must be increased before it is fed to the power amplifier.

Because certain amplifiers possess distortion characteristics, it is possible to utilize these characteristics since such systems are rich in harmonics. By adjusting the grid bias so that the plate distortion is high, it is possible to achieve the desired frequency increase and at the same time have the fundamental frequency crystal-controlled.

Reactance-tube Modulators. Frequency modulation in reactance-tube circuits is accomplished by utilizing the fact that a tube possesses inherent capacitance. (See Figure 3-19). Tube T2 is shunted across the oscil-

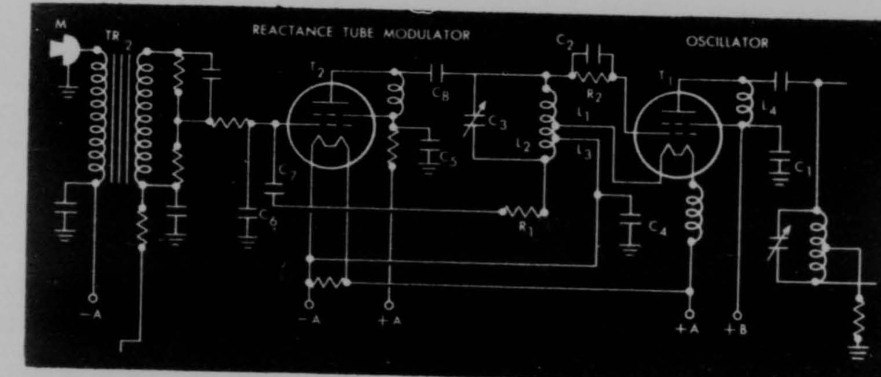


Figure 3-19 Reactance-Tube Modulator

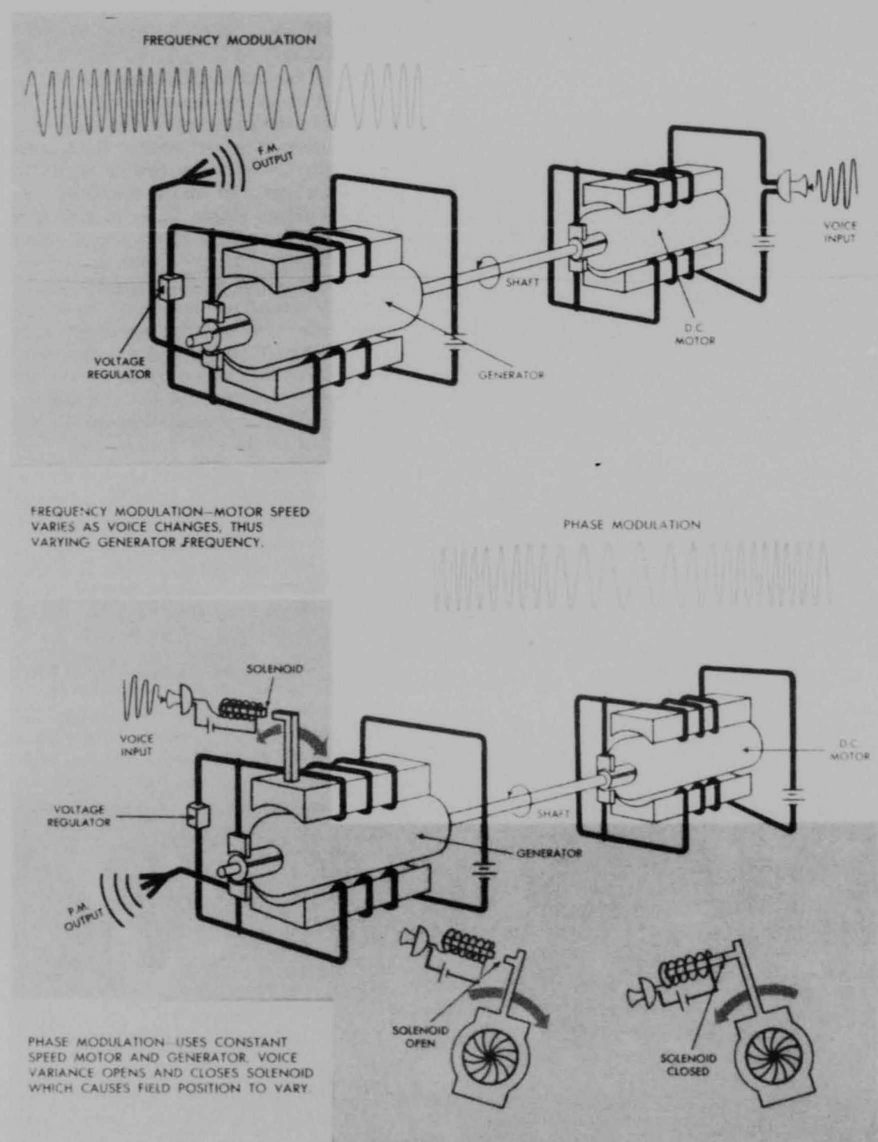


Figure 3-20 Comparison of Principles of FM and PM

lator tank through C8 and the filament circuit and is then made to act as a capacitor. By varying the amount of current flowing through this tube, its capacitive effect across the oscillator can also be varied. The audio-frequency voltage produced by microphone M is coupled through the transformer to the grid of the reactance tube T2. Thus the current through the tube will vary at an audio frequency and the capacitive effect of the tube will vary. This in turn varies the frequency of the oscillator.

Phase Modulators. To understand phase modulation, a form of frequency modulation, a brief review of coil saturation is needed since the principle involves the reactance of an inductance. When current flows through a coil, a magneto-motive force is set up about

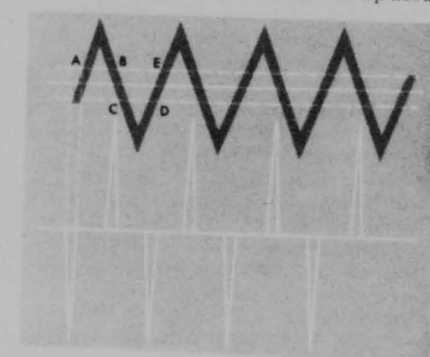


Figure 3-21 Voltage Pulses in Non-Linear Modulator Coil

the coil which varies according to the amount of current flowing through the coil. This magnetomotive force can be compared to voltage. This force sets up a flux about the coil which can be compared to current. The density of this flux depends upon the reluctance (comparable to resistance) of the core of the coil. Coils which have an air core have a reluctance that does not vary with current. Coils having a core of magnetic material will have a reluctance that varies with the current. In air core coils the flux density increases with current flow. In the other type of core, the flux density will increase to a certain point with current increase but beyond that point there is no further increase. If a core is made up of some material which gives a rapid rise in flux with a small change in current, its performance curve is non-linear. This accounts for the name "non-linear reactance coil." A sine wave voltage is applied across such a coil (See Figure 3-21) and as the current through the coil increases from zero to some value such as A, there is a rapid building up of flux as the core is saturated. As the current increases through its maximum to point B there is no further increase in flux. As it decreases through B to zero, there is a rapid change of flux but in the opposite direction. This forms voltage pulses which are 90° after the current peaks. From these voltage pulses, we will have average current values which will have a phase which varies according to the input signal. Such a coil (See Figure 3-21) operates in a circuit as follows:

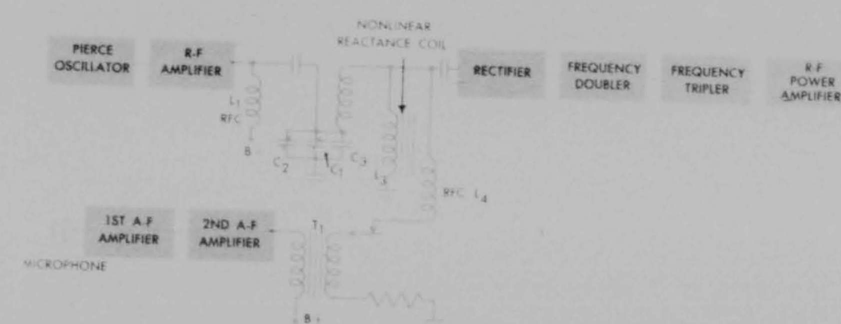


Figure 3-22 Circuit Diagram of FM Transmitter

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Amplifier is fed through coil L1. The frequency of the plate circuit is determined by coils L2 and L3 in series and C1 and C2. C3 is a temperature compensating device. Part of the RF voltage will be developed across L2 and part across L3. In addition to the input RF, the output of the audio section is applied through the RF choke L4 and grounded across L3 which is the non-linear reactance coil. Modulation of the RF is thus accomplished.

Pulse-time Modulation

Pulse-time modulation radio equipment currently employed by the Air Force, is designed for use as a radio link in a wire communications network which may consist of sections of wire lines, carrier telephone or telegraph systems. The set is composed of a pulse-modulated, microwave radio transmitter and receiver with facilities for providing eight two-way voice frequency channels over an unobstructed line-of-sight path. The radio sets are used in pairs, one being located at each end of the line-of-sight path. The average working range of the radio link is from twenty-five to fifty miles, depending upon the characteristics of the intervening terrain and the effective antenna height. Longer radio circuits may be set up by placing the sets in tandem as relay stations.

The conventional radio communications equipment transmits a continuous signal which is a faithful instantaneous reproduction of the audio frequencies superimposed on the carrier frequency. However, in pulse-time modulated radio sets, this is no longer the situation. The pulse-time radio system of communication samples the audio frequencies to be sent and then transmits only these samples. It readily may be seen that the major difference between the conventional radio system and pulse-time modulation system is in the amount of intelligence transmitted.

The receiver in the pulse-time modulation system sorts the received signals into the proper channel and then from the samples of the received signal reconstructs the original intelligence.

Method of Modulation. Existing military pulse-time modulated radio sets are capable of transmitting and receiving eight simultaneous voice channels by means of a single radio frequency (RF) carrier which is transmitted in pulses or short bursts of radio frequency energy. To explain the process by which a pulsed RF carrier may be modulated by one or more audio frequency channels, let us examine the functioning of a typical radio set—in this case the AN TRC-6.

In the time division multiplex, each channel to be transmitted is connected to the line in rapid succession either electronically or by means of a rotating commutator, thus the multichannel signal is composed of interlaced samples of the several channels being transmitted. A large number of these samples are transmitted per unit of time to permit reconstruction of the original signals at the receiver apparatus, where they are separated by another electronic or mechanical commutator synchronized with that at the transmitter.

When no modulation is present in any of the eight voice channels, the transmitted carrier wave is as shown in Figure 3-24. A 2-microsecond synchronizing pulse is followed by eight channel pulses, each of 0-4 microsecond duration, the first of which occurs approximately 6-microseconds after the synchronizing pulse with the remaining seven channel pulses following at approximately 12-microsecond intervals. The next synchronizing pulse occurs approximately 6-microseconds after the eight channel pulses. One synchronizing pulse and eight channel pulses constitute a frame or cycle, which has a duration of 100-microseconds. Ten thousand frames are transmitted per second.

The transmitter fires during the 2-microsecond interval of the synchronizing pulse, then rests, storing up energy until the proper time for a channel pulse to be transmitted. With no modulation signal present, each of the eight channel pulses recurs in the exact center of the 10-microsecond time interval allotted to that particular channel, as indicated by the dotted lines in Figure 3-24.

The process of superimposing voice frequencies on any type of radio frequency carrier is known as modulation. In the pulse-time modulation, the voice frequencies are applied to any single channel and varies the time of occurrence of the channel pulse, with

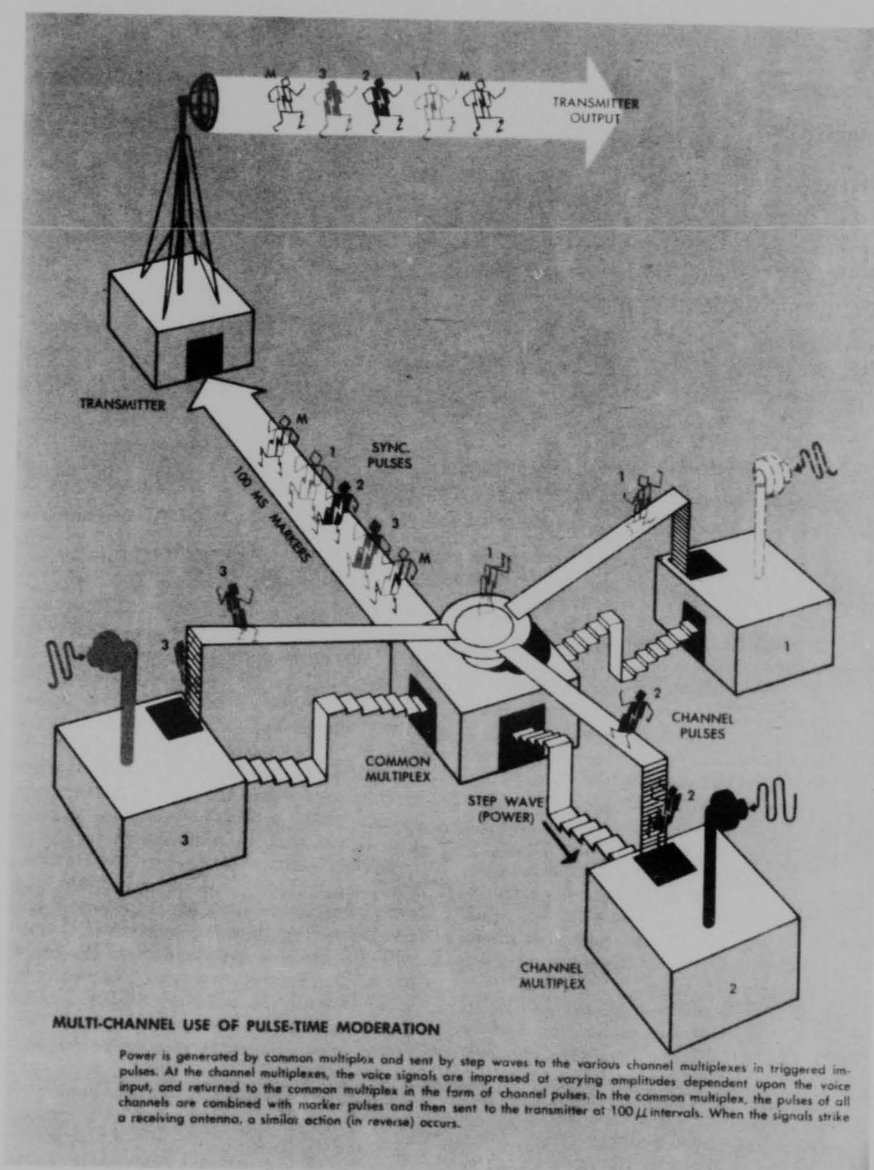

Figure 3-23 Pulse-Time Modulation

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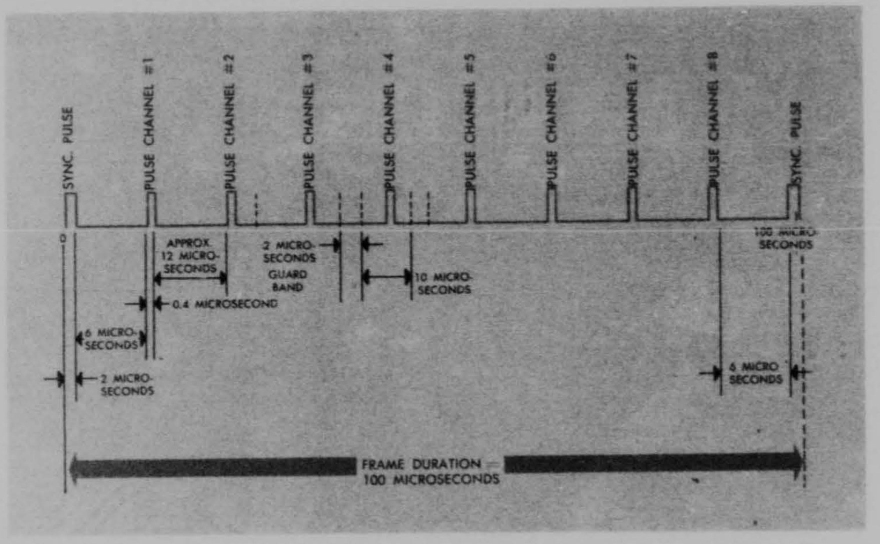

Figure 3-24 Graphic Representation of Pulse-Time Modulated Carrier Wave — No Modulation Present

respect to its unmodulated or rest position. The maximum deviation of the channel pulse from its rest position is plus or minus 5 microseconds. The extent of the deviation depends upon the instantaneous amplitude and polarity of the modulating signal, hence the term pulse-time modulation.

It is noted that the channel period is about 10-microseconds while the interval between channel pulses is approximately 12-micro-seconds. The 2-microseconds interval between the channels is a guard band which serves to separate the channels and reduce the possibility of interchannel crosstalk that might be caused by excursions of a channel pulse into an adjacent channel.

Figure 3-25 is a graphical representation of audio-frequency modulation applied to channels 2, 4, and 6, the remaining channels being unmodulated. The relative positions of the nine pulses which occur in channel 2 during one cycle of a 1,250 cycle per second sine wave are illustrated. Further consideration of channel 2 indicates that pulse A occurs at a time when the modulating signal has neither amplitude nor polarity; hence it is centered in the 10-microsecond channel. Pulse B approximately 100-microseconds later is retarded 0.707 x 5 microseconds, corresponding to the amplitude of the wave at 45 electrical degrees. Pulse C samples the peak amplitude of the wave and is retarded 5-micro-seconds. Pulses F, G, and H are advanced in time indicating that the polarity of the modulating signal has reversed. Channels 4, and 6 may be analyzed in a like manner.

Demodulation. At the receiver the synchronizing pulse is separated from the channel pulses and is utilized to generate eight 10-microsecond gates, synchronized in time with the channel assignments at the transmitter. Each gate is connected to the input of a different channel demodulator, so that the channel is operative only during the expected time of arrival of a pulse for that channel.

After being separated in this manner, the position-modulated pulses for each channel are converted to width-modulated pulses, from which the original modulating signal may be recovered quite easily by means of appropriate low-pass filters. This conversion

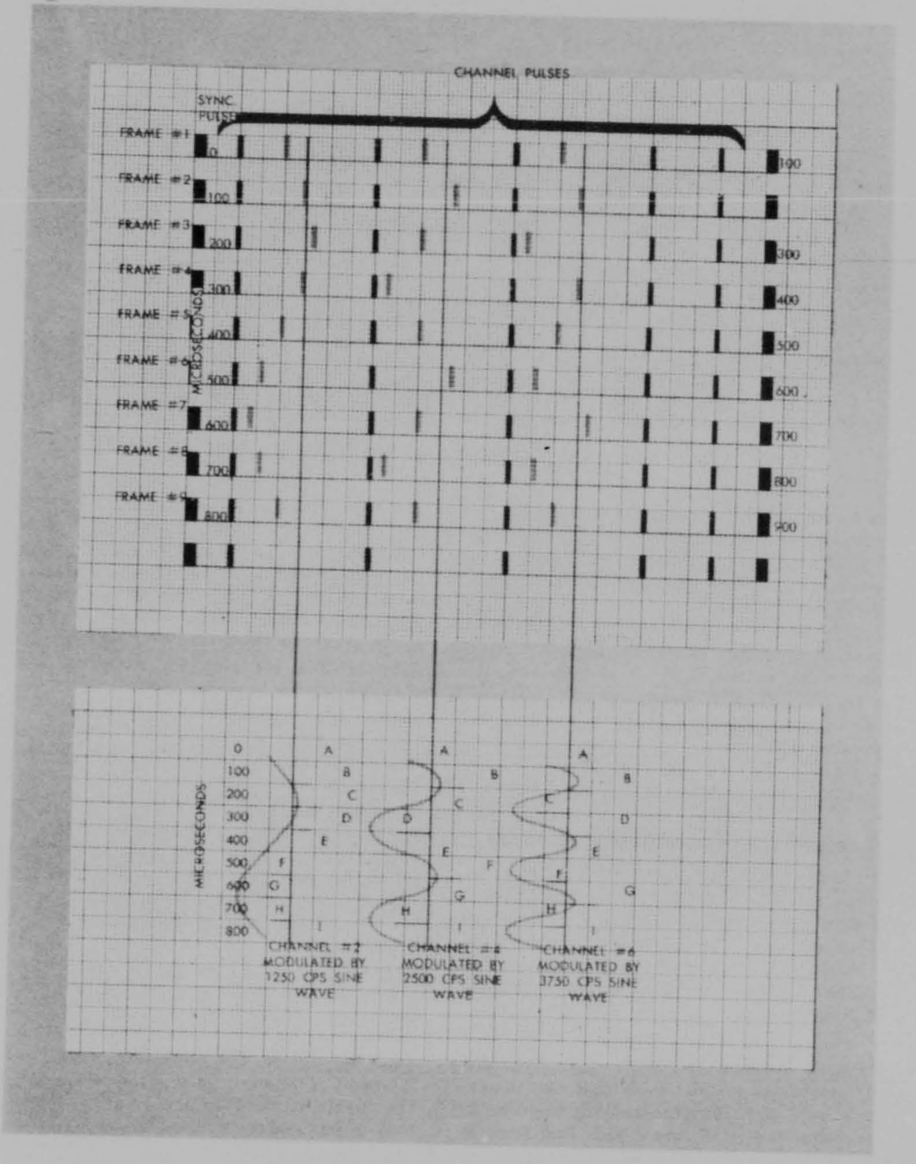

Figure 3-25 Graphic Representation of Pulse-Time Modulation

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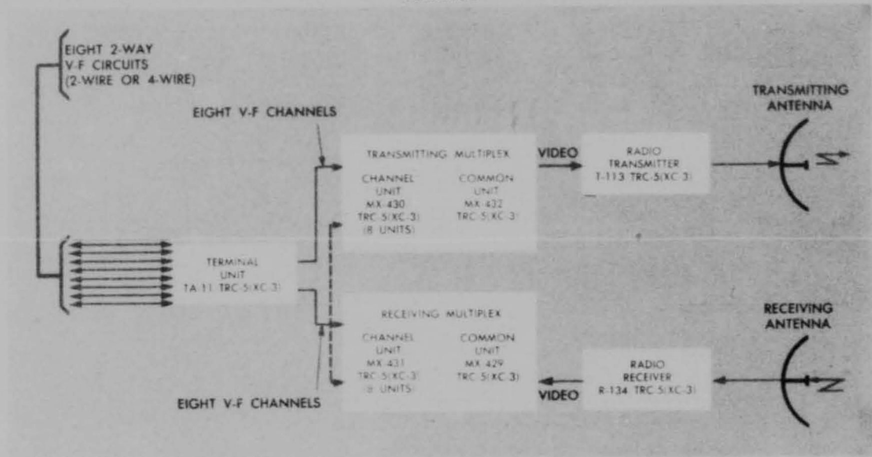

Figure 3-26 Block Diagram of Pulse-Time Modulated Radio Set

is accomplished by using the opening of the channel gate to trigger a flip-flop multivibrator which then conducts and continues to conduct until the incoming pulse arrives. Since the pulses may arrive at any time during the 10-microsecond interval that the gate is open, the pulses passed by the local circuit may vary in length from 10-microseconds when the pulse arrives 5-microseconds late to only 1-microsecond when the pulse occurs 5-microseconds early.

Figure 3-26 is a block diagram of a typical pulse-time modulated radio set.

Comparison of Modulation Methods

Each of the various types of modulation discussed in the text has certain advantages and disadvantages. It is impossible to say that any one type is the "best" since it is necessary to consider the employment of the radio frequency spectrum in which the set will operate.

Figure 3-27 briefly compares the three types of modulation. The principle advantage of amplitude modulation is that only a narrow band of radio frequencies is required to transmit the intelligence. This fact alone is sufficient to cause its use in the lower frequency bands where space in the radio spectrum is at a premium. Frequency modulation and pulse-time modulation require such wide frequency bands for the transmission of intelligence that they waste large portions of the radio frequency spectrum in the lower bands. Therefore, they are confined to the higher bands where there is less congestion in the spectrum. Frequency modulation permits the final RF amplifier to be operated always at its rated power output and is more efficient since no additional power is required when the radio is modulated. However, the final amplifier in an amplitude-modulated radio is less efficient since it operates at only one-fourth rated power output when unmodulated. It operates at full power output only when modulated to 100 per cent. At all other times, it is of some value between these two extremes.

Static either natural or man-made is a source of disturbance in any radio. Static, in general, is amplitude-modulated and contains few, if any, components of frequency modulation. Static is generally more intense at the lower radio frequencies and decreases quite rapidly as the radio frequencies are increased. Frequency modulation will reduce the effects of static to a very great degree, but, unfortunately cannot be employed in the lower frequencies, where the effects of static are most noticeable due to the wide band widths required for transmission. Since

COMPARISON OF MODULATION METHODS

	AMPLITUDE MODULATION	FREQUENCY MODULATION	PULSE-TIME MODULATION
SIGNAL LEVEL FROM TRANSMITTER.	Varies with modulation level.	Remains constant during modulation.	Remains constant during pulses.
AMPLITUDE OF MODULATING VOLTAGE.	Determines instantaneous change in signal level. Stronger the audio signal, greater the instantaneous change in carrier level.	Determines instantaneous deviation in frequency from resting carrier frequency. Stronger audio signal, greater frequency deviation.	Determines instantaneous deviation in time of channel pulse from rest position. Stronger audio signal, greater time deviation.
MODULATING VOLTAGE FREQUENCY.	Determines rate of change of amplitude of r-f wave.	Determines rate at which carrier frequency changes between high and low values.	Determines number of samples transmitted for each cycle of modulating voltage.
SIDE BANDS TRANSMITTED.	Width of transmitted side bands determined by frequency of modulating voltage. Present general limit plus and minus 5 kc each side of the carrier.	Width of transmitted side bands determined by amplitude of modulating voltage. Present limits in military are 40 kc each side of rest frequency. In addition, a 20 kc guard band is provided for separation of adjacent channels. Divided equally on both sides of rest frequency.	Width of transmitted band is determined by pulse width of transmitted pulses. Bandwidth is several times that required by a-m or f-m width may be aproximated of intelligence. The band to transmit the same amount by formula. Bandwidth in mc 1 pulse length in microseconds.
MODULATOR POWER.	One-half plate power input to modulated stage.	Negligible enough to supply plate loss in modulator tube.	Negligible enough to supply plate loss in modulator tube.
CARRIER POWER.	Final amplifier must be capable of supplying four times rated carrier power on 100 percent modulation peaks.	Final amplifier must be able to supply rated carrier power only.	Final amplifier must be able to supply rated carrier power only.
FREQUENCY LIMITATION.	None	Normal above 20 mc, practicable at 2 mc.	Above 1000 mc.
MODULATION SAMPLING.	Continuous	Continuous	Periodic

Figure 3-27 Comparison of Modulation Methods

the intensity of static decreases at higher frequencies, one of the great arguments for frequency-modulated radio stations begins to lose some of its weight.

The employment of pulse-time modulated equipment parallels that of frequency-modulated radio terminal and relay equipment. However, it has two major advantages over frequency modulated terminal and relay equipment:

1. Frequency-modulated terminal and relay equipment is capable of providing four two-way communication channels while the pulse-time modulation provides eight such channels.

2. The distortion between successive relay stations is greatly reduced.

The fact which limits the length of circuits employing frequency-modulated relay equipment is the amount of distortion introduced at each relay. With pulse-time modulated relay equipment, the circuit length is limited by cumulative maintenance rather than the cumulative distortion, which occurs with addition of relays.

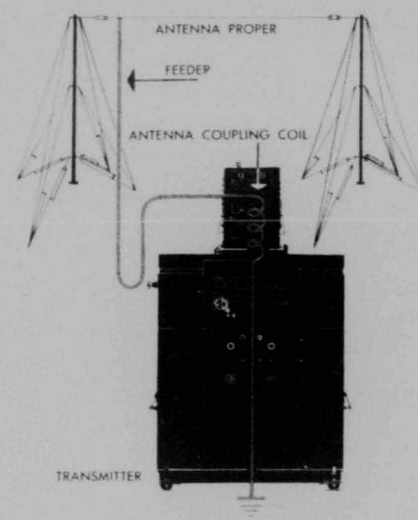

Figure 3-28 Typical Transmitting Antenna System

6. ANTENNAS

General

The device which performs the function of projecting radio waves into space is the antenna. The energy from the transmitter is radiated or sent into space by the transmitting antenna. This energy travels through space in the form of an electric field which cuts across the receiving antenna and induces a voltage in it. Receiving antennas for LF, MF, and HF, normally, are not very critical, and, therefore, do not require extreme care in design for satisfactory operation.

The proper design of the transmitting antenna system is important, as the antenna must be able to radiate efficiently the power supplied by the transmitter. This antenna must be very exact in its dimensions and must be properly constructed. Otherwise, low efficiency will result.

A complete transmitting antenna system consists of three distinct parts, as illustrated in Figure 3-28. These are the coupling device, for coupling the output of the transmitter to the feeder; the feeder, or transmission line which carries the energy to the antenna; and the antenna proper, which radiates the radio energy into space.

There are many shapes and sizes of antennas employed in radio transmission. A few of the many types are shown in Figure 3-29. Some of the factors which determine the type, size, and shape of the transmitting antenna to be used are:

The frequency of operation on the transmitter.

The amount of power to be radiated.

The general direction of the distant receiving station.

Relationship of Frequency and Wave Length

The wave length represents the distance traveled by the wave in a length of time corresponding to one cycle, assuming that a sinusoidal force produced the wave. Since the radio wave travels with the velocity of light, the relationship between wave length

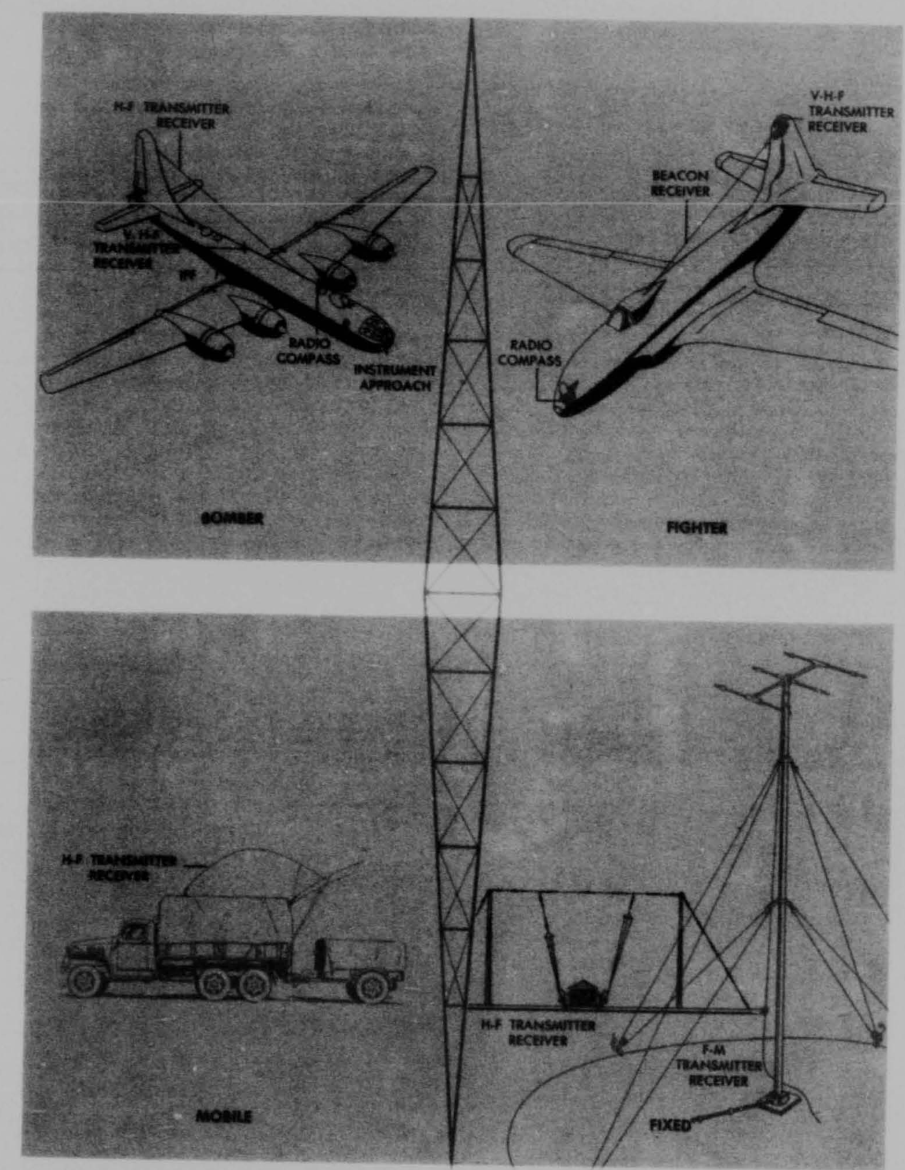

Figure 3-29 Types of Antennas

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and frequency exists. This relationship is:

$$\lambda = \frac{300,000,000}{f}$$

where:

λ = wave lengths in meters
f = frequency in cycles per second

or:

$$\lambda = \frac{186,000}{f}$$

where:

λ = wave lengths in miles
f = frequency in cycles per second

Generation of Electromagnetic Waves

The Infinite Line. An alternating voltage impressed on an open-wire transmission line of infinite length, causes an electro magnetic wave to be propagated along the line at approximately the velocity of light. The applied voltage causes an electrostatic field to exist between the wires. The current flowing in the wires causes magnetic lines of force to exist around the wires. Figure 3-30 illustrates the manner in which these two fields exist. The two fields are at right angles to each other and both are perpendicular to the length of the wire. The magnitude of each field is directly proportional to the amplitude of the force which produces it.

In order to explain the phenomenon of wave-travel more fully, assume that one cycle of a sine-wave voltage whose frequency is 186,300 cycles per second (wave length 1 mile) is impressed on an open-wire line of infinite length (Figure 3-31). Figure 3-31 A represents the condition of the line and the voltage generator at time zero. As the voltage starts positive from zero (B), a weak electromagnetic field is started down the line. The amplitude of the voltage increases until at one-quarter cycle (90°) it is at a maximum value at the source (C). At the same instant, the electromagnetic field has reached its maximum at the source. However, at this instant the weak electromagnetic field initially set up has traveled one-quarter wave length down the line. During the next quarter-cycle, the generator voltage decreases to zero and the electromagnetic field also diminishes to zero at the source as the first half-cycle is completed. At this instant, the leading edge of the electromagnetic field has traveled a distance of

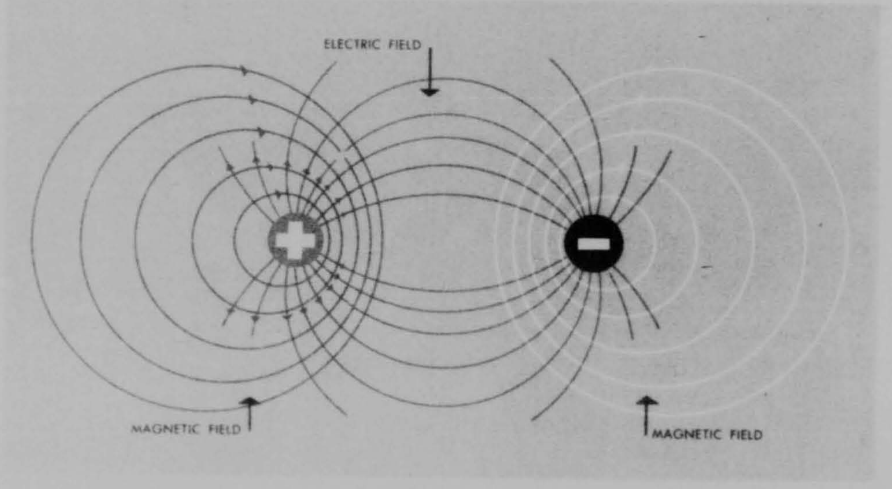

Figure 3-30 End-On View of a Transmission Line. (The Two Fields Constitute an Electro-Magnetic Wave).

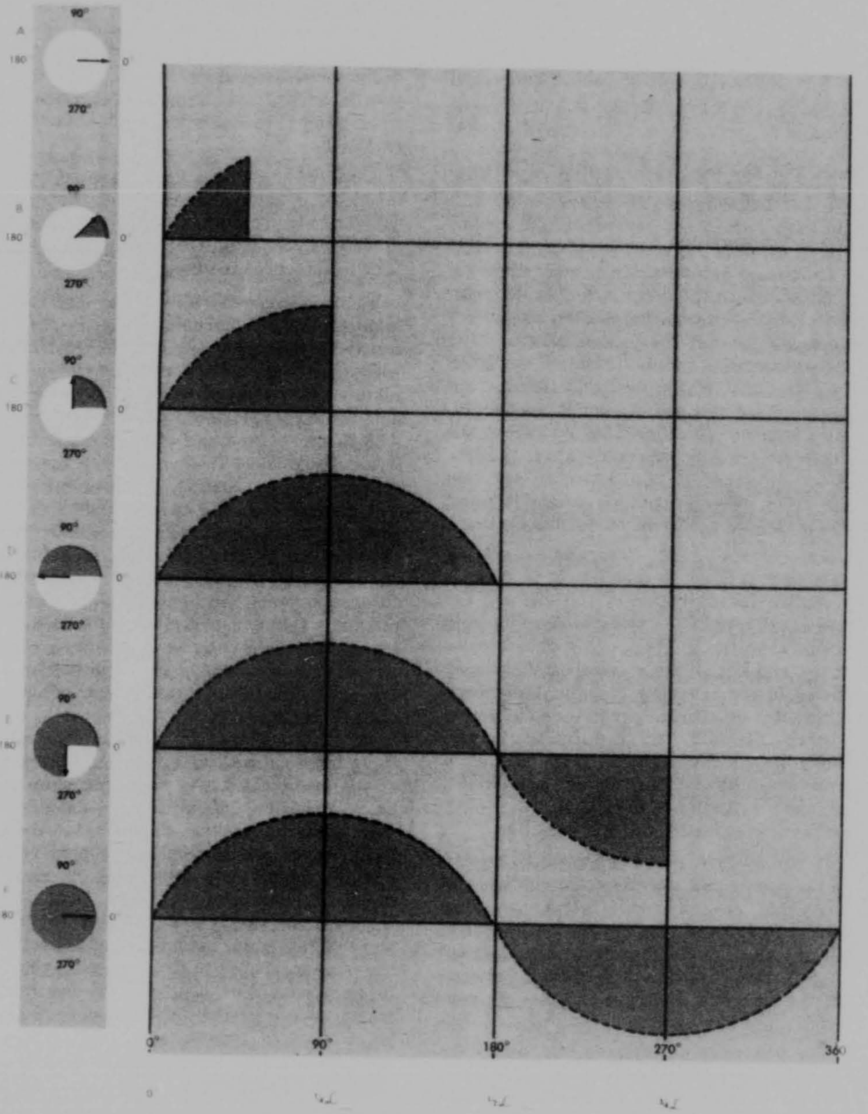

Figure 3-31 One Cycle of Alternating Voltage Impressed on an Infinite Line

one-half wave length down the line. Figure 3-31 D shows the wave at the end of this instant. Figures 3-31 E and F show the wave at the three-quarter, and one-cycle, points. As the voltage generator begins the second cycle, the same phenomenon is repeated. At the end of the second cycle, however, the first weak electromagnetic wave has traveled down the line two wave lengths, in this example two miles.

Wave Reflections

The preceding discussion is based upon the condition of an infinitely long line. In practice of course this is impossible, but a condition will be met in practice in which the transmission line appears to be infinite. When the impedance of the load and the line are the same, its behavior is as if it were an infinite transmission line. This results in the maximum transfer of energy along the line in one direction. It is a desirable condition and every effort is made to attain it, since this is the most efficient mode of operation.

Unfortunately, this condition is not always encountered in practice. It is difficult to match the impedance of the line and the load exactly, or if the transmission line conductor material is changed, a discontinuity occurs and not all the wave energy is transmitted in one direction. Some of the energy is reflected back to the sending end at points where a discontinuity or mismatch occurs. When an electromagnetic wave strikes a large discontinuity, such as an open circuit, complete reflection occurs since the wave cannot travel further in that direction.

In the study of wave reflection as related to radio antennas, we are interested only in lines that are electrically short. In other words, in lines which are only a few wave lengths along at the frequency of excitation. In this case, the line attenuation between the sending and receiving end may be neglected since it is small.

The traveling electromagnetic wave has its counterpart in hydraulics, in the case of a long straight canal. If a disturbance is made at one end of the canal, a series of waves will travel along the canal. If a series of floats were placed on the surface of the water and measurement of the instantaneous values of the heights were made as the wave passed, these values would be similar to the instantaneous values of voltage and current obtained in the infinite line. If, however, the floats were so arranged that they would remain at the maximum height after the wave passed, then a straight line would be obtained.

Now, suppose that a dam is placed across the canal in such a manner that the waves will strike it. There will then be a piling up of water at the dam which will start a wave back in the opposite direction.

In like manner, if an electric line is not infinitely long or terminated in its characteristic impedance but is open-circuited, then, when the wave strikes the end, it will be reflected. The electric wave in traveling has half of its energy stored up in the magnetic field (current), and half of the energy stored in the electric field (voltage). When the wave strikes the open circuit, the magnetic field will collapse, for the current must become zero. However, a changing magnetic field produces an electric field. This is the principle upon which all generators and transformers operate. The energy stored in the magnetic field will, therefore, be turned into energy in an electric field and will be added to the existing field, so that the voltage at the open circuit will be increased. This increased voltage will start a wave traveling back in the opposite direction, and, since there has been nothing to absorb any energy at the open circuit, the returning wave will be of the same magnitude as the original wave. As the electric field starts moving back, it will set up a magnetic field again, and the energy will once more be equally divided between the two fields. As the electric field has simply been doubled at the instant of reflection, the voltage of the returning wave starts out in the same phase as the original wave. The magnetic wave is in opposite phase to the incident wave at the point of open circuit, and, since the two voltages are equal and do not add to zero, they must remain in phase.

In Figure 3-32A is shown a plot of the two voltage waves which are present on an open-circuited line at some instant. The total voltage at any point on the line at that instant is also shown. It will be noticed that the reflected wave is obtained by folding back on the line, from the point of reflection, the initial wave as it would have been beyond the open circuit has the line continued on. In Figure 3-32B to I, this process is continued for later instants. When the two waves are added point by point, it will be seen that at some points the resultant wave is always zero. These points occur at odd quarter-wave lengths from the open circuit, because at such a position the reflected wave has traveled an odd number of half-wave lengths since it passed this point as part of the initial wave. At even quarter-wave lengths from the open circuit, the resultant voltage is always twice the value of either wave, since the two waves at these points are equal and in the same direction.

In Figure 3-32J, all the resultant waves obtained for the different instants are plotted on top of each other to permit a better comparison. It will be noticed that voltage varies with time and space. At every point along the line, the voltage reaches a maximum at the same instant, but the magnitude of this maximum voltage varies sinusoidally along the line. It should be noted in contrast, that on the line terminated in its characteristic impedance the maximum voltage occurs at different instants for different points on the line but is the same value for all points when there is no reflection. If a voltmeter is moved along the open-circuited line, a curve similar to Figure 3-32K would be obtained. The readings always will be positive since the meter cannot take account of phase. Waves which can be detected by a meter which records average results are called standing waves and are different from the traveling waves which were first discussed. The points of minimum voltage are called the "nodes" of voltage while the points of maximum voltage are called antinodes. The voltage at the nodes is not actually zero since there is always some loss caused by resistance as the wave travels along the lines. Since the returned wave is slightly smaller, it will not entirely neutralize the initial wave at these points, but at high frequencies there is a close approximation to this ideal condition. These curves also represent current on a short-circuited line since the current wave is reflected without change in phase in this case.

Figures 3-33, A to I, show the two waves of current on the line for different instants. It should be remembered that while a voltage wave and a current wave are discussed as though they were distinct, the voltage and current together are necessary for a physical wave, since one cannot exist without the other, but each can be considered separately in plotting results. It will be noted that the current has been reversed at the open circuit so that the two waves add up to zero at that point. As the instantaneous values are added point by point, it will be observed that there is also a standing wave of current. This wave is the same as would be obtained for voltage if the reflection had occurred a quarter-wave down the line, and the nodes of current occur at the antinodes of voltage and vice versa.

These curves also represent voltage on a short-circuited line since phase reversal occurs on reflection in this case also.

Electromagnetic Radiation

Now, consider the special case of resonant lines $\frac{\lambda}{2}$ long at the frequency of excitation. From Figures 3-32K and 3-33K, the voltage and current distribution along one side of this line would be as illustrated in Figure 3-34.

Little of the energy along such a line escapes even though much of the actual generated power exists in the electromagnetic field as evidenced by the standing waves of voltage and current. It is evident from a study of Figures 3-32 and 3-33 that the phase angle (θ) between the current and voltage waves in Figure 3-34 is 90 electrical degrees. The energy, in the form of an electromagnetic wave, flows into the parallel wire circuit and is transmitted along the line to the distant open end where it is reflected back toward the sending end. If the parallel wires of Figure 3-34 have negligible attenuation, then all the energy that is sent out will be reflected and the net power input to the line must be zero. The generator voltage at the sending end forces a current into the line, but since the power taken from the line is

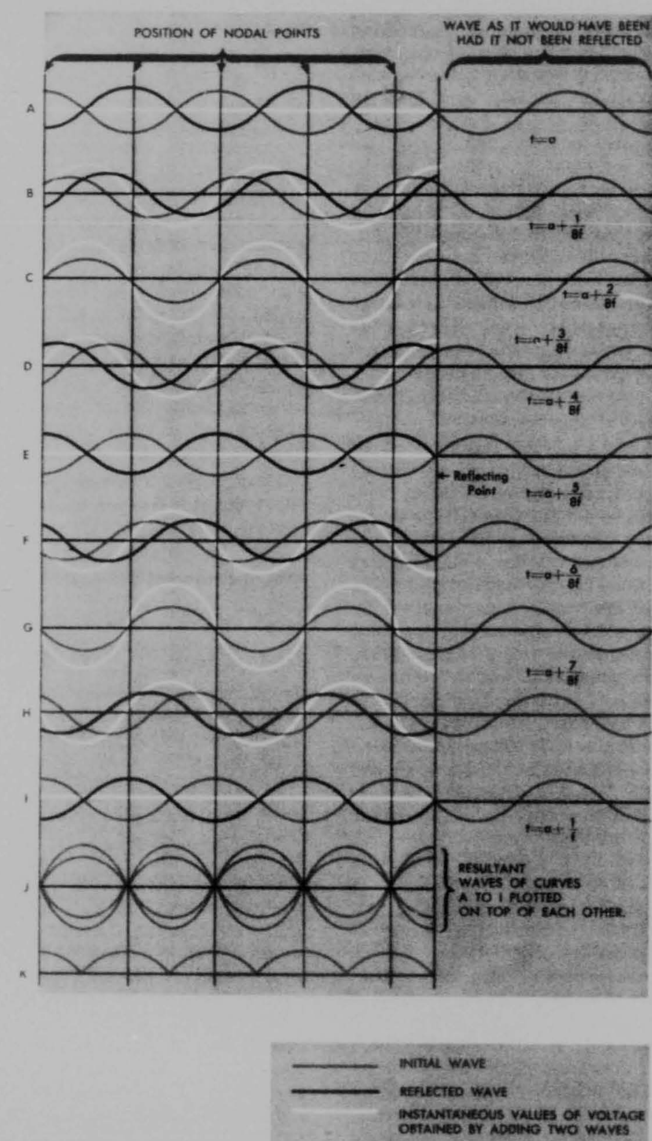

Figure 3-32 Instantaneous Distribution of Voltage on Open-Circuited Lines

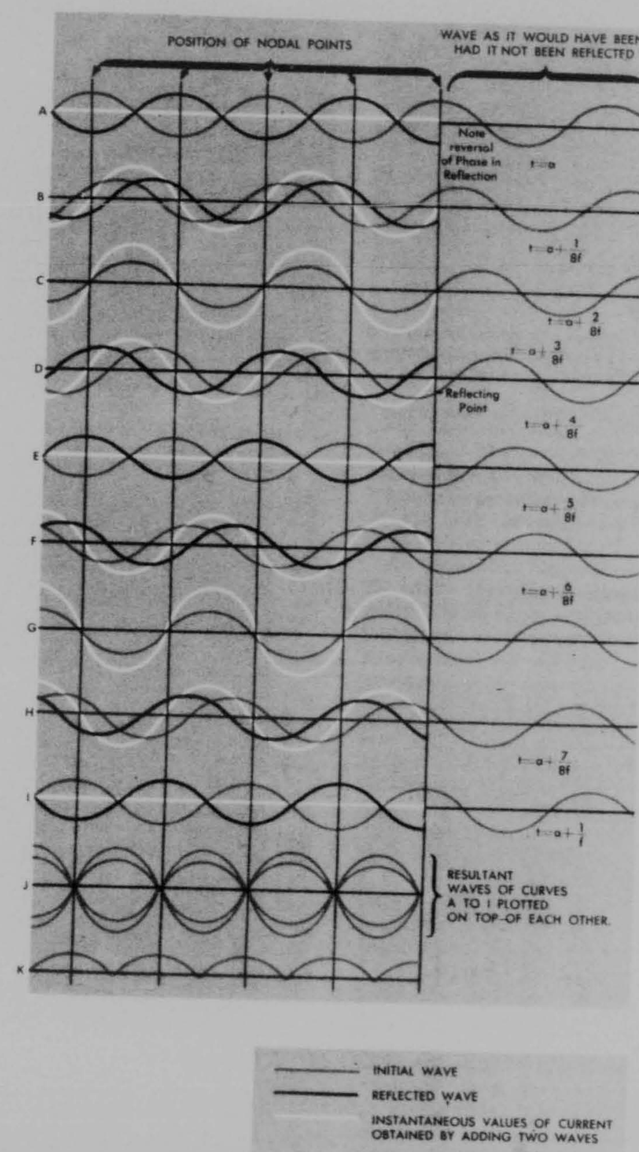

Figure 3-33 Instantaneous Distribution of Current on Open-Circuited Lines

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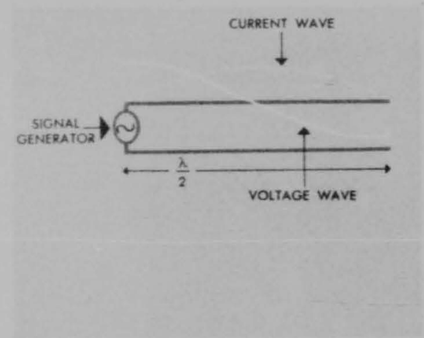


Standing waves of voltage and current on one side of an open-circuited transmission line one-half wave-length long at the frequency of excitation.

Figure 3-34 Standing Waves of Voltage and Current

zero, the value of the power equation must, therefore, be zero. The power equation is:

$$P = EI \cos \theta$$

where:

P = power in watts
E = impressed voltage
I = current in amperes
Cos θ = power factor or the cosine of the angle between the voltage and current vectors.

An inspection of Figure 3-34 reveals that the voltage and current vectors have real value. Therefore, in order that the power be zero the value of cos θ must be zero. Cosine 90° is zero. This means that the voltage and current are 90 electrical degrees apart with respect to the time with which they pass through corresponding values.

In Figure 3-35, the instantaneous values of the voltage and current for a half-wave length line are plotted in the upper portion of diagram. The impedance for such a line is plotted below. This shows how the impedance varies as the distance from the open circuited end is varied, and, therefore, is a plot of impedance versus length of line. The input impedance of a half-wave length open-circuited line must be pure resistance.

Now suppose that the open ends of the half-wave line are separated as illustrated in Figure 3-36. It will be found that the generator now sends power into the line and that the input impedance is no longer pure reactance but contains a resistance component. The value of the power equation is no longer zero. In other words, the voltage and current are no longer ninety electrical degrees apart when they pass through corresponding values. The system is now dissipating energy. Since it has been assumed that the wires have no attenuation, where does the energy go? The answer is this: The magnetic and electric field components of the electromagnetic wave are no longer largely confined to a small region, but now excite a large volume of space and are starting to radiate electromagnetic waves into space. Imagine the electric and magnetic fields surrounding the line in Figure 3-34. It is readily

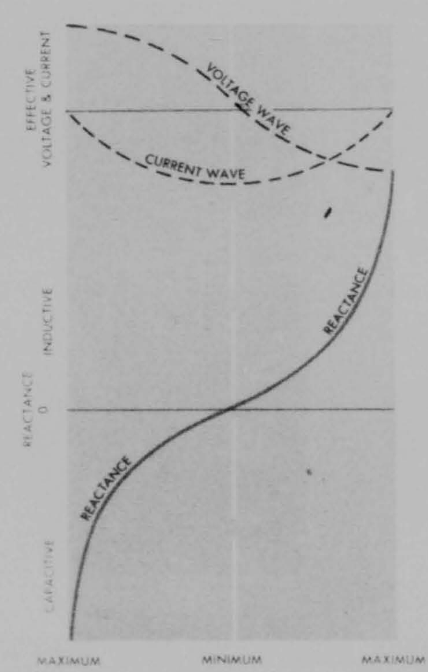


Figure 3-35 Variation of Impedance of an Open-Circuited Line One-Half Wavelength Long and Without Attenuation.

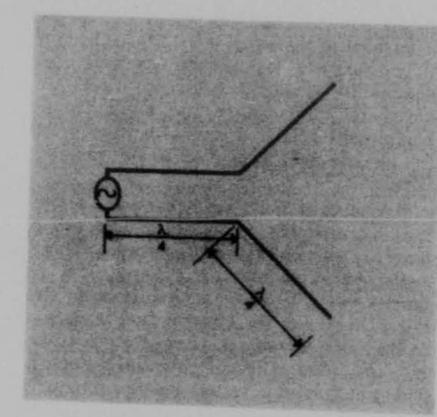


Figure 3-36 A Transmission Line Half-Wave-length Long with Open End of the Line Spread

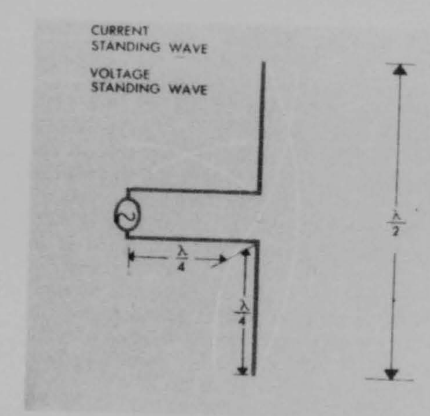
seen that the two fields are confined to a limited space. However, if the lines are now separated as in Figure 3-36, it is observed that the two fields will occupy a much larger space.

If the wires are further separated as in Figure 3-37, the system now becomes a quarter-wave resonant transmission line energizing a half-wave length antenna. The transmission line is energized at a point of high impedance and is terminated (at the antenna) at a point of low impedance. The length of the transmission line and of the radiating elements depend on the wavelength of the radio waves employed. If the lengths of the transmission line and radiating elements are proper, the entire system will be resonant at the frequency employed. In this case, a very small part of the power will be lost by the transmission line and practically all losses which occur in the system will be in the form of an electromagnetic wave radiated from the antenna.

To explain more fully how the radiation of energy actually occurs, suppose now that the radio-frequency generator (radio transmitter) is connected between points A and B in Figure 3-38. This gives the vertical radiator of Figure 3-37. Assume that the transmitter is impressing a pure sine-wave voltage on the antenna.

At that part of the cycle in which the upper generator terminal is negative, electrons in the antenna will be repelled and will flow up wire A. At the same instant, the lower generator terminal will be positive and will attract the electrons up from wire B. In conventional thinking, the direction of current flow is opposite that of the electron flow. Since the conventional current is flowing down the antenna the magnetic lines of force will encircle the antenna as illustrated by the solid circles. When the polarity of the generator reverses during the next one-half cycle, the direction current flow is reversed and consequently the magnetic lines of force will encircle the antenna in the opposite direction. Also, when the upper terminal of the generator is negative and the lower terminal positive, electric lines of force will be established as indicated by the broken lines between the two portions of the antenna. When the generator voltage is reversed during the next half-cycle, the electric lines of force will be reversed.

At frequencies below the radio frequency spectrum (below approximately 30 kc.), practically all of the energy in the two fields is returned to the source by the end of each



The half-wavelength transmission line by modification becomes a half-wave antenna energized by a quarter-wavelength transmission line.

Figure 3-37 Modification of a Half-Wavelength Transmission Line.

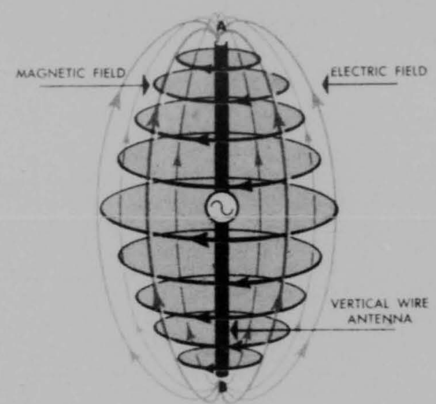


Figure 3-38 Electric and Magnetic Fields Around a Vertical Wire Antenna

half cycle, and before the fields of opposite polarity expand into the space around the wire. As the frequency of excitation is increased, however, the collapsing fields of one-half cycle of the applied voltage do not completely return to the wire before it is met by the expanding field, or opposite polarity, of the next half-cycle. For example, the collapsing field produced by the positive half-cycle does not completely return to the circuit by the time it is met by the expanding field produced by the negative half-cycle. This expanding field of the negative half-cycle forces a portion of the returning field from the positive half-cycle to propagate out into space and never to return to the source. Thus, some of the electromagnetic energy from each half-cycle of the impressed voltage is forced away from the antenna as an electromagnetic wave. This wave consists of two components; the magnetic field at right angles to the electric field. Furthermore, the wave travels away from the antenna with the velocity of light and in a direction perpendicular to the plane of the fields.

Polarity of Electromagnetic Waves

The direction of the electric field, i.e., the electric lines of force with respect to the earth, determines the polarity of a radio wave. A radio wave whose electric field is perpendicular to the earth is said to be vertically polarized and one whose electric field is parallel to the earth is said to be horizontally polarized. Vertical antennas radiate predominantly vertically polarized waves, and horizontal antennas radiate predominantly horizontally polarized waves. In other words, the electric field is parallel to the radiating wire.

Horizontally polarized waves are attenuated more rapidly in traveling over ground than are vertically polarized waves. This is explained as follows: A difference of potential exists between two points in an electric field. When the electric field is parallel to the earth, the earth acts as a short circuit between these points of potential difference. This short circuit causes small currents to flow in the earth's surface which results in the loss of radio energy from the wave.

If the electric field is perpendicular to the earth, as in the case of vertically polarized waves, the points of potential difference in the electric field are not in contact with the earth and no earth currents will flow since there is no point of potential difference on the earth's surface. Therefore, there are very small ground losses present. Radio waves traveling along the earth's surface tend toward vertical polarization regardless of the antenna polarization.

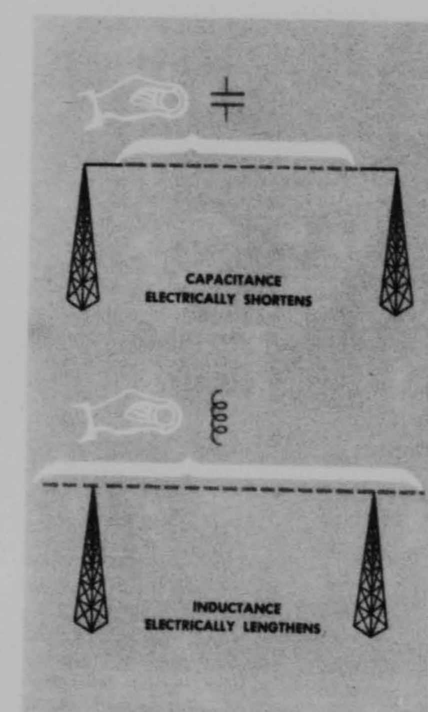
Antenna Dimensions as Related to Wave Lengths

The velocity at which an electro-magnetic wave travels through a medium depends upon the dielectric constant of that medium. At radio frequencies, the dielectric constant of air is unit. For all practical purposes, an electromagnetic wave is considered to travel with the velocity of light through air and the vacuum of space. However, the velocity will be reduced somewhat by other media, such as a wire, whose dielectric constant is greater than unity. When the dielectric constant is greater than unit, the velocity of propagation is reduced.

The addition of reactive elements (capacitance or inductance) at some point in the line or the antenna has the effect of electrically shortening or lengthening the line, depending upon the type of reactance added. The addition of capacitive reactance in series

with a given antenna causes it to be resonant at a higher frequency than the physical length of the wire would indicate. The line has been electrically shortened. On the other hand, the addition of inductance in series with a given antenna will cause it to be resonant at a lower frequency than the physical length would indicate. This line has been electrically lengthened.

If there were no inherent lumped reactance in antennas, their physical length could be found by dividing the velocity of light by the desired operating frequency. However, since antennas normally are supported by insulators at the antenna terminals, a small amount of capacitive reaction is present at these points. This capacitance normally is referred to as **end effect** and is compensated for in the frequency range from 1.5 to 30 mc by making the physical length of the antenna 0.95 that of the free space wave length.



A relationship can be found which will establish the length in feet of an antenna one half wave length long, or longer, to be resonant at any given frequency between 1.5 and 30 mc a follow:

$$L\ (\text{feet}) = \frac{492 \times (n - 0.05)}{f\ (\text{mc})}$$

Where 492 is a constant representing one-half wave length in feet at a frequency of one megacycle; N is the number of half-wave lengths in the antenna; and 0.05 is a constant which compensates for end effect and is sufficiently accurate for all practical purposes in this frequency range.

Free Space Radiation Patterns

The radiation from an infinitesimally small length of wire carrying a radio frequency current is a maximum in the plane perpendicular to the wire and minimum along its axis. The magnitude of the radiation field varies as the sine of the angle between the wire and a line from the wire through the point at which the radiation intensity is measured.

Next consider a wire of appreciable length to be made up of a chain of infinitesimal radiators. It will be found that the field strength is no longer distributed in the same way as for the elemental length. The total intensity of radiation at some point in space is now the vector summation of the intensities of all the elemental radiators at that point in space. For example, the radiation from one elemental radiator may reinforce the radiation from another elemental radiator if they arrive at the point **in phase**, i.e., their path lengths are the same or differ by any number of full wave lengths. Complete cancellation may occur in like manner if they arrive at the point **out of phase**, i.e., their path lengths differ by any odd number of half-wave lengths. These are the two extremes—one of complete reinforcement and one of complete cancellation. In between these two points, the intensity varies and is dependent upon the phase relationship between the intensities of the several elemental radiators concerned.

Now consider the radiation pattern for a

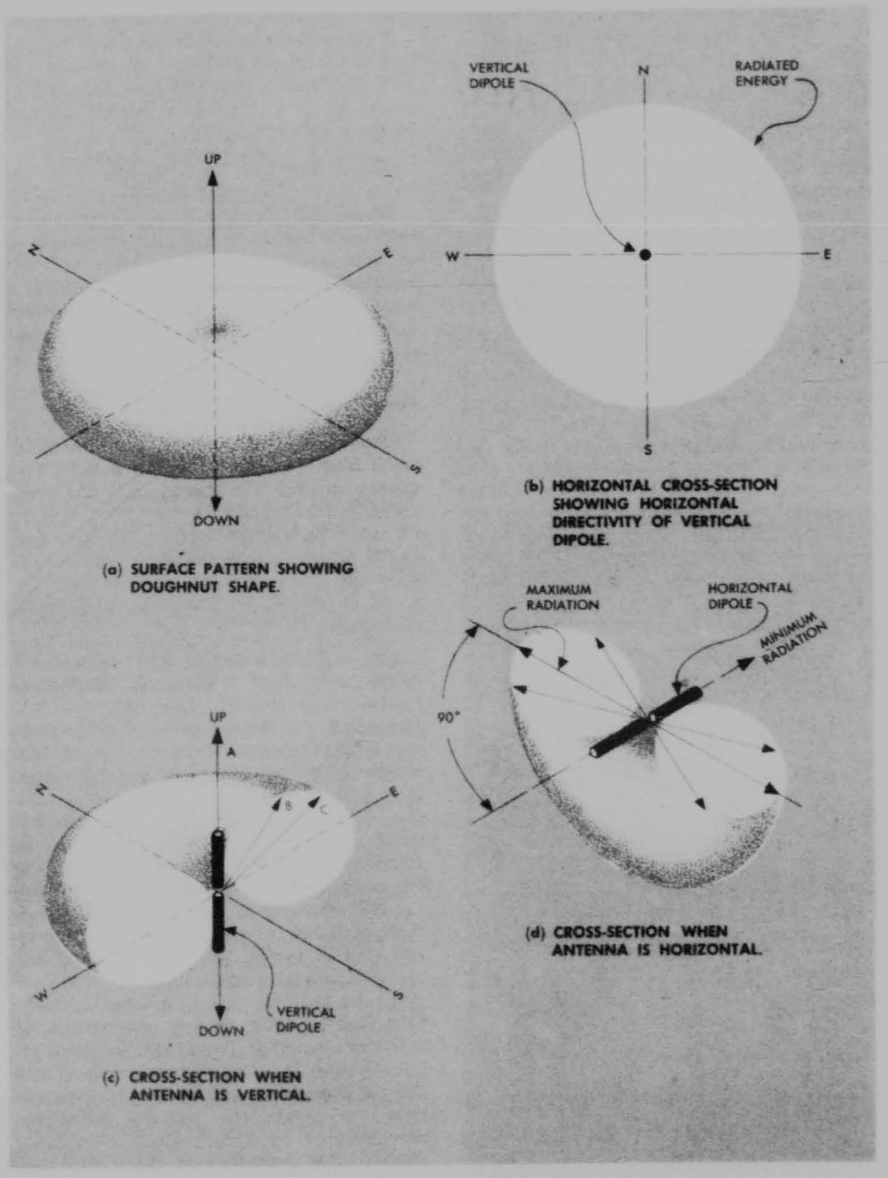


Figure 3-39 Radiation Pattern of a Half-Wavelength Antenna in Free Space.

half-wave antenna remote from the ground or any object that might influence its radiation pattern. Since the current is greatest at the center of the antenna, maximum radiation takes place at this point and practically no radiation takes place at the ends where the current is zero. The maximum radiation for this antenna would be in a plane perpendicular to the conductor. The shape of the radiation pattern resembles a doughnut with the antenna wire passing through its center, as illustrated in Figure 3-39. With a vertical antenna, the radiation pattern will be nondirectional in the horizontal plane, and with a horizontal antenna it will be nondirectional in the vertical plane. The points in the pattern where the radiation is zero are called "nulls" and the points on the pattern represented by the curved line (area between the nulls) are known as "lobes."

Modification of Free Space Patterns by Ground Reflection

The performance of an antenna, particularly with respect to directive properties is considerably modified by the presence of the earth. The earth acts like a huge reflector for those waves which are radiated from the antenna lower than the horizontal. The process of the reflection of radio waves by the earth is similar to that by which light is reflected from a mirror.

The value of the signal strength as measured at some point P (Figure 3-41) in space will depend upon the phase relationship of the direct ray and the reflected ray at point P, and will be the vector sum of the two rays. The factors which determine the magnitude of the resultant wave are the orientation of the antenna with the earth, the height of the antenna above the earth, its length (if vertical) and the characteristics of the reflecting surface.

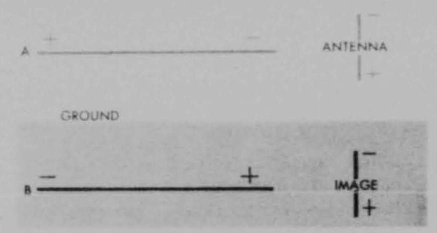
It is frequently necessary for the communications officer to predict the lobe pattern to be found in the radiation of a radio transmitter operating at frequencies above 30 mc in order to determine the performance of a communication set or a radar station. For this reason, ground reflection and the formation of lobe patterns will be presented in the manner they are employed in USAF communications.

For the purpose of studying the vertical angles at which radiation will be a maximum or minimum, it is convenient to consider that the reflected wave is generated by an image antenna below the surface of the earth. This concept is similar to that employed in studying the laws of mirrors.

In the case of a perfect earth (infinite conductivity), the magnitude of the reflected wave will be exactly that of the incident wave. This is the situation normally assumed by the communications officer, since it will provide results that are sufficiently accurate in most cases. The currents in corresponding parts of real antenna and the image antenna, i.e., parts lying on the same vertical line and at the same distance from the earth's surface, are of the same magnitude. The direction of current flow is such that the vertical component of the current in the image is in the same direction as the vertical component of the current in the corresponding part of real antenna. The horizontal component of the current in the image is in the opposite direction from the current in the corresponding part of the real antenna (Figure 3-40).

Since the reflected wave may be considered as being generated by the image antenna, it is apparent that it will be opposite in polarity to the wave generated by the real antenna. If the real antenna is horizontal and is instantaneously charged so that one end is positive and the other end negative, then the image antenna, also horizontal, is oppositely polarized. (Figure 3-40.)

The electric and magnetic fields existing in space above the earth, in the presence of a perfect earth, are exactly the same fields that would be produced in this region by the joint action of the real antenna and its image antenna with the earth removed. Since the total field in any direction represents the vector sum of the direct wave and the reflected wave, the total field will be maximum at vertical angles where the direct and reflected waves arrive in phase, and will be minimum at vertical angles where the direct and reflected waves arrive out of phase. The value of the field will have values between the maximum and minimum that depend upon the phase difference of the two waves at that point. If there were no phase shift in the



(A) illustrates the current distribution for the horizontal component of current in the image and corresponding parts of the actual antenna. (B) illustrates the vertical component of the current in the image and corresponding parts of the actual antenna.

Figure 3-40 Horizontal and Vertical Components of Current.

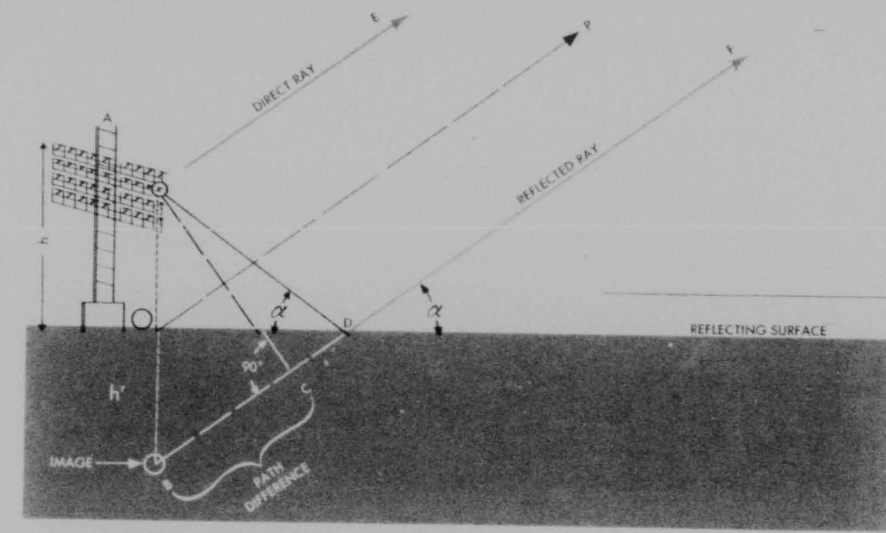
reflected wave at the point of reflection, the minimum field strength at some point P in space would occur when the path of the reflected wave was exactly one-half wavelength (or any odd number of half-wave lengths) longer than the direct path.

The case just discussed would be true if there were no phase shift of the wave at the point of reflection. However, when a radio wave is reflected from a reflecting surface having infinite conductivity, the angle of incidence equals the angle of reflection, the amplitude of the incident wave, and the reflected wave may have exactly the same or exactly the opposite phase of the incident wave. In practice, it may be assumed that the horizontally polarized wave will undergo a 180-degree phase shift at the point of reflection, while a vertically polarized wave will undergo practically no phase shift for angles of incidence useful in radio communications.

The following discussion for developing the vertical angles for minimum and maximum radiation is based upon the employment of horizontally polarized waves. The student communication officer is urged to develop a similar discussion for vertically polarized waves. Furthermore, in this discussion the curvature of the earth is neglected, in order to simplify the mathematics. This causes no appreciable error if the antenna is not more than 200 or 300 feet above the reflecting surface.

The radio waves from antenna **A** (Figure 3-41) may arrive at point **P** in space by way of two paths, the direct path **AEP** and the reflected path **ADFP**. The strength of the signal at point **P** is the resultant of the two waves reaching that point. The reflected wave (for horizontally polarized waves) undergoes a 180 degree (one-half wavelength) phase reversal at the point of reflection, and its phase is further delayed with respect to that of the direct wave because of the longer path that it must travel. The antenna **A** is **h** units above the earth and the image antenna is located at the same distance below the ground. The antenna and its image lie on a line which is perpendicular to the earth at point **O**. If the distance **OP** is very great compared to **h**, then path **AEP** may be considered parallel to path **DFP**. Construct the line **AC**, through point **A** and perpendicular to **BDFP**. Since paths **AE** and **DF** are assumed to be parallel, then geometrically, it is evident that the reflected path length is physically longer than the direct path by the amount **BC**. It is convenient to express this path difference in half-wavelengths. When the difference in the path length is equal to one-half-wavelength or any odd number of half-wavelengths the reflected wave arrives at point **P**, 180 electrical degrees behind the direct wave as a result of this extra path length. However, horizontally polarized waves undergo an additional phase reversal of 180 electrical degrees at the point of reflection-point **D**. Therefore, when the path difference **BC** is equal to odd half-wavelengths, the reflected wave will lag the direct wave by 360 electrical degrees (one wavelength or multiples thereof) in arriving at point **P** and the resultant field strength at point **P** will be maximum. Since both waves are of equal strength and in phase, the resultant field is the vector summation of the two waves at that point. It is evident that the resultant field will be double the value of the individual waves.

When the path difference is equal to one wavelength or any even number of half-wavelengths, the reflected wave lags the direct wave by an amount equal to the path difference plus one-half wavelength due to the 180 electrical degree phase shift at the



At any distant point P, the field strength will be the resultant of two rays, one direct from the antenna, the other reflected from the ground. The reflected ray travels farther than the direct ray by the distance BC, assuming the reflected ray originates, in effect, from the image antenna.

Figure 3-41 Direct and Reflected Rays

point of reflection. Therefore, the resultant field strength at point **P** will be zero since the two waves are arriving 180 degrees out of phase.

Critical Angles. Critical angles are those at which maximum or minimum radiation occurs and are measured from a line tangent to the earth at the base of the antenna. The mathematical relationship between the quantities may be derived from Figure 3-41 as follows:

Since the angle **BAC** is nearly equal to the angle of elevation **DOP** of point **P**, then as long as the mean path is very great compared to the antenna height **h**, the path difference **BC** may be expressed as:

$$BC = \frac{n\lambda}{2} = 2h \text{ sine } \alpha$$

$$\text{or sine} = \frac{nh}{4h}$$

For small angles, i.e., angles less than 10 degrees, the sine of the angle equals the angle itself expressed in radians (one radian equals 57.3 degrees). Than

$$d = \frac{n}{4h} \text{ radians}$$

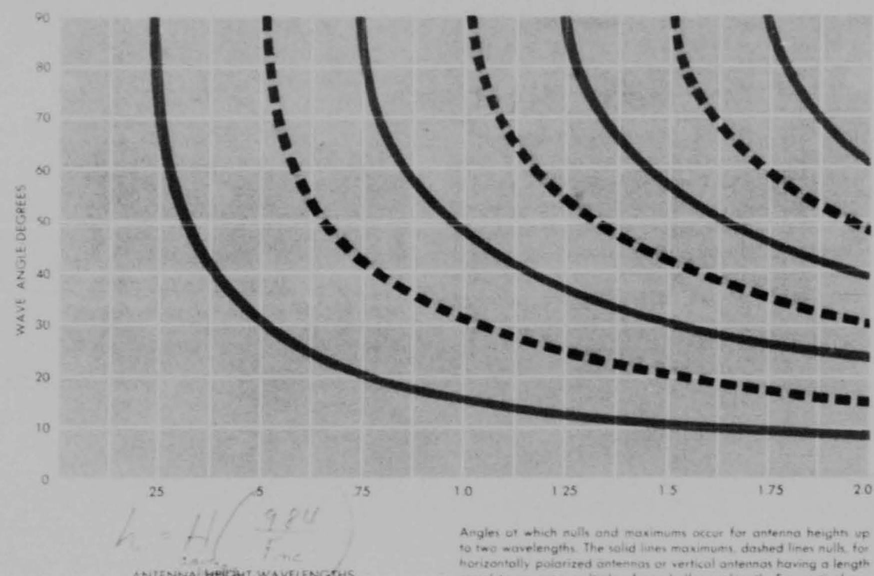
or

$$\alpha = 14.3\ n\lambda \text{ degrees}$$

Where λ = the wavelength in feet
h = antenna height in feet
n = the number of half wavelengths in the path difference.

For horizontally polarized antennas odd values of half-wavelengths (i.e., n-1, 3, 5, ...), the direct and reflected wave will arrive at point **P** and produce a maximum field strength, even values of n (i.e., 2, 4, 6, ...) will produce minimum field strength at point **P**.

Figure 3-42 shows the relationship between antenna height above ground and the wave angles for horizontal and vertical antennas.



Angles at which nulls and maximums occur for antenna heights up to two wavelengths. The solid lines maximums, dashed lines nulls, for horizontally polarized antennas or vertical antennas having a length equal to an even multiple of one-half wavelength. For vertical antennas an odd multiple of half waves long, the dashed lines are maximums and the solid lines are nulls.

Figure 3-42 Relationship Between Antenna Height and Wave Angle

Construction of Vertical Coverage Diagram. Once the mean antenna height above the reflecting surface has been determined, it is a relatively simple process to construct the estimated vertical coverage diagram from theoretical considerations. It has been shown that the field strength becomes a maximum or minimum whenever **n** in equation 10 is an integer. It can be shown that the curve containing all points at which the signal strength is a specified value is given by the expression

$$r = r\ max\ sine\ (90°\ n)$$

Where **r max** is the maximum range at which this value of signal strength occurs and **n** is essentially the angle of elevation in units of $\lambda/4h$ radians, employing equations 10 and 11 an estimated vertical coverage chart may be constructed.

Example: It is desired to construct an expected vertical coverage diagram for a radio set operating at 100 mc with the antenna 70 feet above the reflecting surface $\lambda = 9.82$ feet. Antenna horizontally polarized. Maximum range 200 miles.

Solution:

1. Compute α the angle of the first maximum for the given antenna height and operating frequency from equation

$$\alpha = \frac{14.3\ n\lambda}{n} = 14.3 \times 1 \times 9.82 = 2.0 \text{ degrees}$$

2. Draw through the origin a line at this angle of elevation above the reference line (the horizontal line drawn through a point directly underneath the antenna at the height of the reflecting surface). See Figure 3-43. Draw the line representing the first null in a like manner. Label each line to indicate a maximum or null. As many lines of maximum and nulls may be drawn as desired. Since the height scale is greatly distorted, the angle cannot be plotted with a protractor. It is convenient to remember that at a distance of 109 miles an altitude of 10,000 feet corresponds to one degree in angle of elevation. In the example, the first

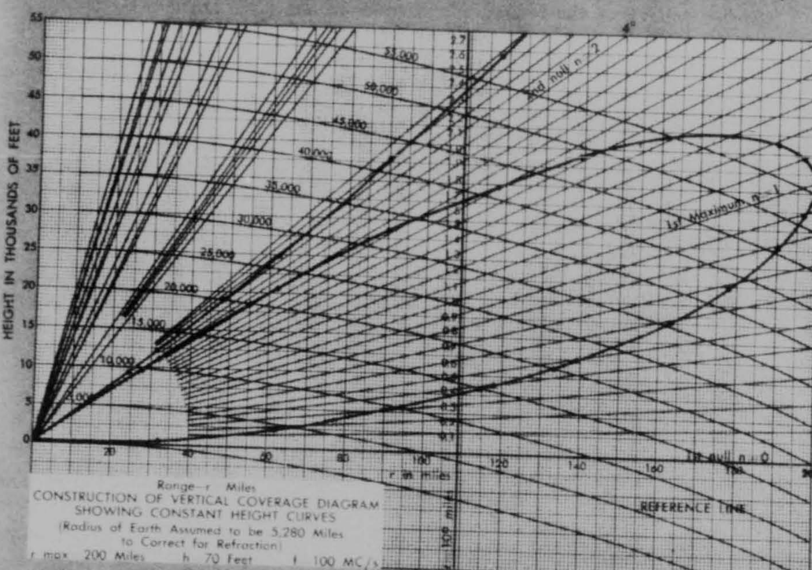


Figure No. 3-43 Expected Vertical Coverage Diagram

N = n + A FRACTION		SIN (90N)	EXAMPLE			
N—EVEN	N—ODD		N—EVEN	r	N—ODD	r
N = 0.0	N + 1.0	0	0	0	2	0
N = 0.1	N = 0.9	0.16	0.1	32	1.9	32
N = 0.2	N = 0.8	0.31	0.2	62	1.8	62
N = 0.3	N = 0.7	0.45	0.3	90	1.7	90
N = 0.4	N = 0.6	0.59	0.4	118	1.6	118
N = 0.5	N = 0.5	0.70	0.5	140	1.5	140
N = 0.6	N = 0.4	0.81	0.6	162	1.4	162
N = 0.7	N = 0.3	0.89	0.7	178	1.3	178
N = 0.8	N = 0.2	0.95	0.8	190	1.2	190
N = 0.9	N = 0.1	0.99	0.9	198	1.1	198
N = 1.0	N = 0.0	1.00	1.0	200	1.0	200

Figure 3-44 Factor Table

maximum is plotted at 20,000 feet above the reference line at a range of 109 miles. The first null is 40,000 feet above the reference line.

3. Additional points on the coverage diagram may be obtained from equation 11. Divide into tenths the vertical distance between any two adjacent lines of critical angle just constructed. Number each division from bottom to top from N + 0.1 to N + 0.9 respectively. N represents the first digit of **n**, the multiple of the critical angle (N = O for the horizontal reference line). Prepare a table similar to Figure 3-44. Place a straight edge through origin and 0.5 in Figure 3-43, then refer to Figure 3-44 and under N — even find 0.5. The next column **r** gives the distance 140 miles at which this signal strength will occur. Plot this value in Figure 3-43. Repeat this operation for the other points and connect them with a smooth curve. The curve represents all points of equal signal strength in the first lobe and under the assumed conditions for a vertical cross section.

A horizontal coverage diagram is made by plotting contours of equal signal strength at given altitude versus range from the station. This information is gathered from several vertical coverage diagrams if the height of the reflecting surface varies in different directions. If the reflecting surface remains the same in all directions from the station, the horizontal coverage diagram is obtained by rotating the vertical coverage diagram about its vertical axis.

The communications officer should become thoroughly familiar with these coverage diagrams since they prove invaluable in estimating communications and radar equipment performance under given conditions. The method described is sufficiently accurate for military operations when used within its proper limits, i.e., not to exceed 10 degrees and the antenna height not to exceed 500 feet.

Size of Reflection Zone. Reflection from the earth's surface is caused by radiation from circulating currents induced in the ground by the lower portion of the radio wave. The reflected energy received at point **P**, Figure 3-41, does not come from point **D** alone but from a large elliptical area surrounding this point. This area, called the first reflection zone, is characterized by the fact that for all points within it, the distance from antenna to ground to the point in space exceeds the shortest reflected wave path by less than a half-wavelength. Thus the radiation contributed by all the currents within this zone give helpful contributions to the reflected field strength at point **P**. The dimensions of the ellipse vary with frequency, the antenna height above the reflecting surface, and the angle of elevation. For the angle of the first maximum above a flat earth, the base of the antenna to the near point of the reflection zone can be estimated from the expression (Figure 3-45):

$Pn = 0.7\ h^2$ feet

The distance to the far point is:

$pf = 23\ h^2$ feet

The width is:

$W = 5.6h$ feet

The distance from the base of the antenna to the point **D** (Figure 3-45) where the wave reflection occurs for the first maximum is:

$Pr = 4\ h^2$ feet

It is evident from equation 15 that the area of the reflecting zone nearest the antenna contributes more to the reflected wave than does the more distant portion of the zone.

The concept of the reflecting zone is useful for approximating the area over which the surface height should be averaged in order to determine the mean antenna height above the reflecting zone. It provides an idea of the area required for perfect reflction of radio waves. The large size of the reflection zone at low angles of radiation shows why minor irregularities of the earth's surface do not materially upset the regularity of the mirror-like reflection for the longer wavelength. However, the reflecting zone concept is not intended to give quantitative answers about the amount of reflection. Its sole use is largely qualitative. It should properly be used only to give an estimate on the order of magnitude for the areas of the reflecting zone necessary to provide the reflections.

The reflection zone is a large factor in the operation of relatively long-wave radar equipment—those operating below approxi-

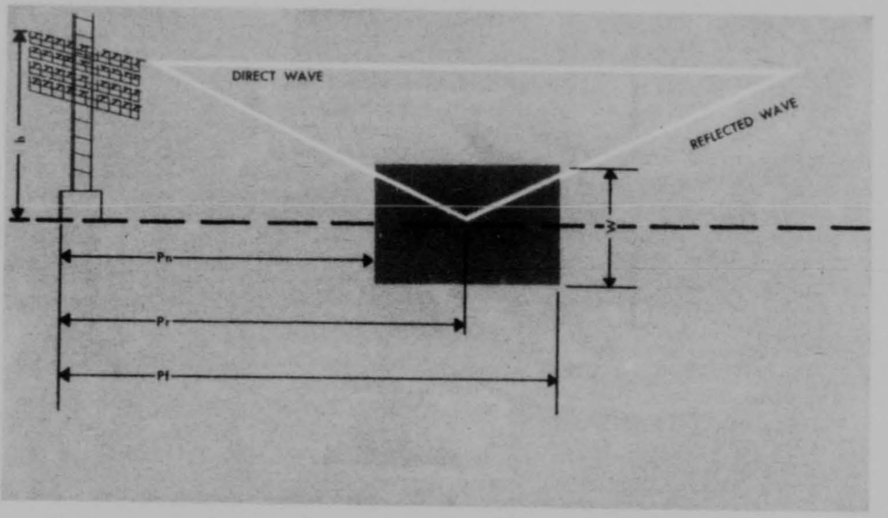


Figure 3-45 Dimensions of the Reflection Zone

mately 2000 megacycles. However, equipment operating above this point is not aided materially in its range capabilities due to ground reflection. This may be readily understood if the wavelength of the radio wave is compared to the physical dimensions of the ground irregularities. As the wavelength decreases, the reflecting surface appears increasingly rougher, and regular reflection no longer takes place.

The waves are now reflected at random and the scattering is so complete that no regular reinforcement occurs. In other words, the radiation patterns of microwave radiation approaches that of the free space pattern.

Characteristics of Half-wave Antenna Patterns. The antenna radiation pattern is that space about the antenna where the intensity of the resultant radiation (the vector sum of the direct and reflexed waves) is equal to certain fixed minimum standard. The envelopes of the radiation lobes are loci of points at which all measurements of radiation strength are equal and of the minimum fixed standard value. The standard of radiation intensity upon which the minimum fixed standard is based is some threshold value, usually expressed in microvolts per meter or in decibels above or below one microvolt per meter.

The radiation pattern for a half-wave antenna in free space is doughnut-shaped with minimum radiation along the axis of the wire and maximum radiation in a plane perpendicular to the wire (Figure 3-39).

Radiation patterns for vertical antennas are nondirectional and in the horizontal plane regardless of their length. The length of the vertical antenna and its height above ground determine the vertical angles at which maximum and minimum radiation occur. Figures 3-46 through 3-49 are representations of radiation patterns for a vertical half-wave antenna at several heights above ground. These are theoretical patterns assuming a perfect conducting ground. Except for the fact that the maximum radiation is not purely horizontal because of ground losses, they are fairly representative of actual practice. The practical result of ground losses is to curve the lower end of the pattern upward, somewhat as shown by the dotted lines. These diagrams illustrate the importance of height in relation to frequency. The higher the antenna the sharper the

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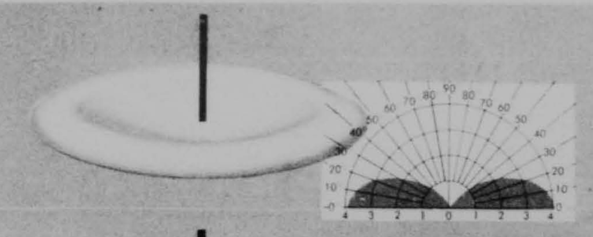

Figure 3-46 Three-Dimensional and Graphic Diagram of the Radiation Pattern Which Exists About a Vertical Half-Wavelength Antenna One-Quarter Wavelength Above Ground.

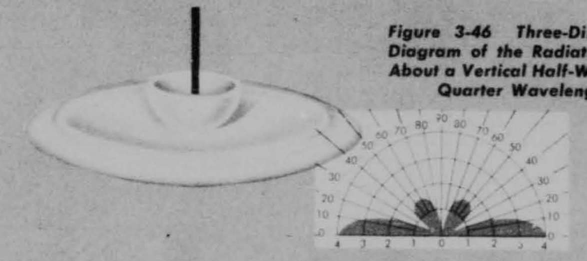

Figure 3-47 Three-Dimensional and Graphic Diagram of the Radiation Pattern Which Exists About a Vertical Half-Wavelength Antenna One-Half Wavelength Above Ground.

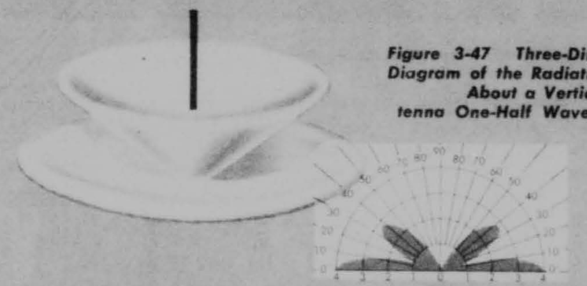

Figure 3-48 Three-Dimensional and Graphic Diagram of the Radiation Pattern Which Exists About a Vertical Half-Wavelength Antenna Three-Quarters Wavelength Above Ground.

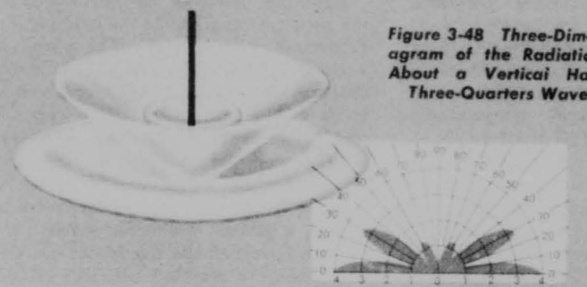

Figure 3-49 Three-Dimensional and Graphic Diagram of the Radiation Pattern Which Exists About a Vertical Half-Wavelength Antenna One Wavelength Above Ground

directive characteristics in the vertical plane. If conditions permit, a height should be chosen which concentrates the radiation at the vertical angle most suitable for the length of transmission path and operating frequency. At frequencies above 30 megacycles, when the space wave is the principal mode of propagation, it is best to have the antenna as high as possible, increasing the radio range, so as to clear the antenna of energy-absorbing objects in the vicinity. The height used, however, should be such that a null will not appear in the region of the most useful angles of radiation.

Radiation patterns for horizontal antennas are directional in the horizontal and vertical planes. The height of the antenna above ground determines its vertical directivity; its length determines its horizontal directivity. The shape of horizontal half-wavelength antenna radiation patterns are illustrated by Figures 3-50 through 3-55 for several heights above ground. Since horizontal half-wavelength antennas are directional in the horizontal plane, i.e., the horizontal pattern is not circular, it would take an infinite number of azimuth profiles such as these to give a complete picture of the vertical characteristics in all horizontal directions. In these figures, the shape of the vertical characteristics is shown for the plane of the wire, perpendicular to the wire, at the midpoint (maximum radiation). At intermediate azimuths, the vertical characteristics of the pattern will be an integration of the vertical characteristics of the two limits illustrated.

It is observed from these polar diagrams that the intensity of radiation is greatest in the plane at right angles to the center of the wire, and is minimum in the plane of the wire. This characteristic of horizontal half-wavelength antennas is more pronounced at low angles of radiation than at high angles of radiation, especially at frequencies of operation where the critical frequency is such that a wave leaving the antennas at almost vertical angles will be reflected from the ionosphere to modify, somewhat, the radiation pattern at high angles. Figure 3-56 is a horizontal polar diagram of a horizontal half-wavelength antenna pattern showing the modification in the shape of the radiation pattern at several vertical angles. The pattern represented by the dot-dash line represents the radiation intensity about the antenna at all azimuths for a vertical angle of 9 degrees. The solid line represents the intensity for a vertical angle of 15 degrees. The dashed line represents the intensity for a vertical angle of 30 degrees.

Characteristics of Long Wire Radiation Patterns. Vertical angles of maximum and minimum radiation for horizontal antennas one wavelength or more long are similar to those for horizontal half wavelength antennas, at equivalent heights. As the length of the antenna is increased to one wavelength or more in multiples of half wavelengths, the horizontal directivity changes. The radiation tends to concentrate more and more off the ends of the wire as the length is increased although some minor lobes appear and provide some radiation in other directions. Figure 3-57. It is apparent from the figure that the horizontal directivity of long-wire antennas depends upon the length of the antenna in multiples of half-wavelengths. Furthermore, the long wire horizontal antenna radiates more power in its most favorable direction. Figure 3-57 illustrates the variation in radiation resistance and power in the major lobe of long wire antennas. It may be seen that, as the length of an antenna is increased, the gain in favorable directions is increased over that of a half-wavelength antenna.

The term "gain" as applied to an antenna system is a measure of the directivity of the antenna radiation pattern as compared with a standard antenna. Quantitatively, the gain is a ratio of power which must be supplied to the standard antenna to deliver a particular field strength, in the desired direction, to the power supplied to the directional antenna system to obtain the same field strength in the same direction. "Gain" may be expressed directly or in terms of decibels.

Rhombic Antennas

The rhombic antenna differs somewhat in principle from the antenna previously described. The rhombic antenna has practically a uniform distribution of current and voltage

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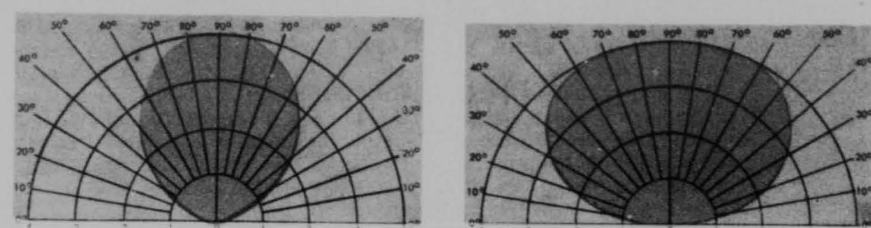
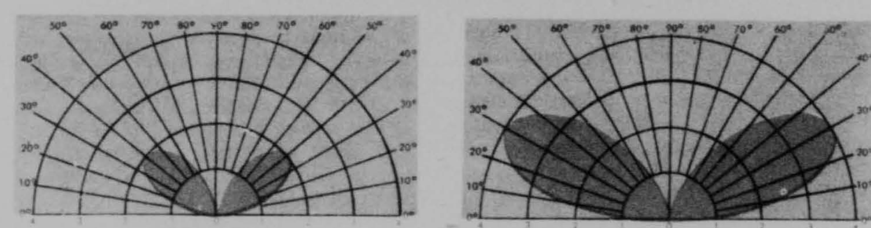


In Direction of Wire

At Right Angles to Wire

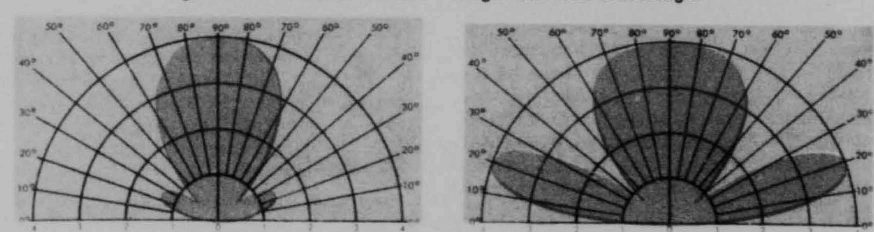
Figure 3-50 Radiation Pattern — Height One-Quarter Wavelength



In Direction of Wire

At Right Angles to Wire

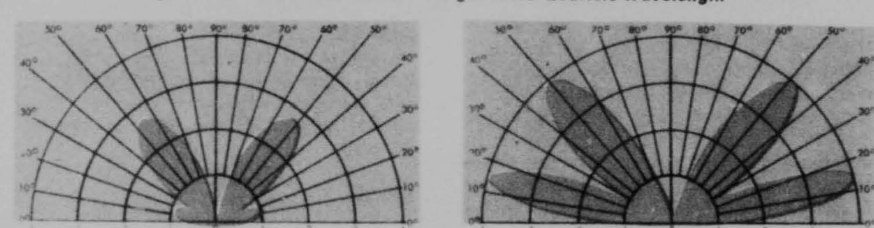
Figure 3-51 Radiation Pattern — Height One-Half Wavelength



In Direction of Wire

At Right Angles to Wire

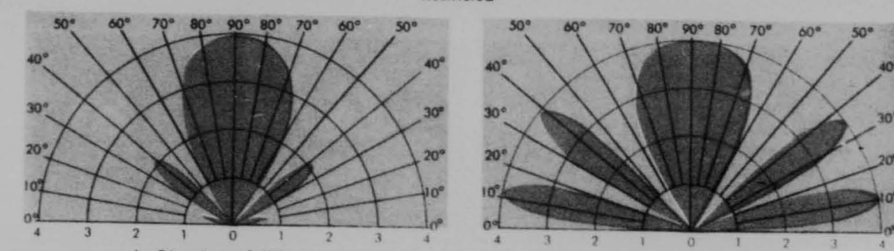
Figure 3-52 Radiation Pattern — Height Three-Quarters Wavelength



In Direction of Wire

At Right Angles to Wire

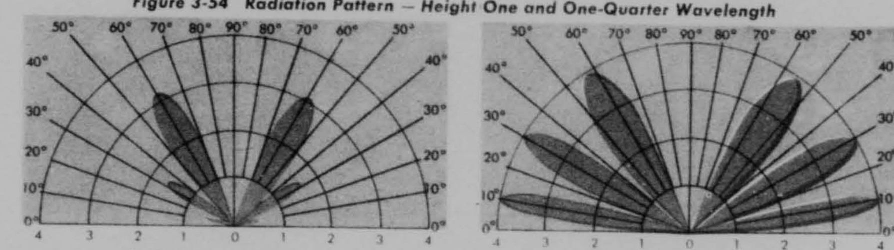
Figure 3-53 Radiation Pattern — Height One Wavelength



In Direction of Wire

At Right Angles to Wire

Figure 3-54 Radiation Pattern — Height One and One-Quarter Wavelength



In Direction of Wire

At Right Angles to Wire

Figure 3-55 Radiation Pattern — Height One and One-Half Wavelength

in all parts of the antenna. The types previously discussed operate under conditions which produce standing waves of current and voltage.

In its elementary form, such an antenna would consist of a single wire, grounded at the far end through a resistor having a value equal to the characteristic impedance of the antenna.

This termination, just as in the case of an ordinary transmission line, eliminates standing waves. The current decreases uniformly along the wire as the terminated end is approached, the decrease being caused by energy radiation and resistance loss in the wire. The energy remaining when the end of the antenna is reached is dissipated in the terminating resistor. For such an antenna to be a good radiator, it must be several wave lengths long at the frequency of excitation since the current in the wire is relatively small. Therefore, a longer antenna is necessary in order to radiate an amount of energy equivalent to that which would be radiated by a shorter antenna with standing waves. This type of antenna must not be so close to the ground that the return path through the ground will cause cancellation of the radiation. If the wire is sufficiently long, it will be practically nonreso-

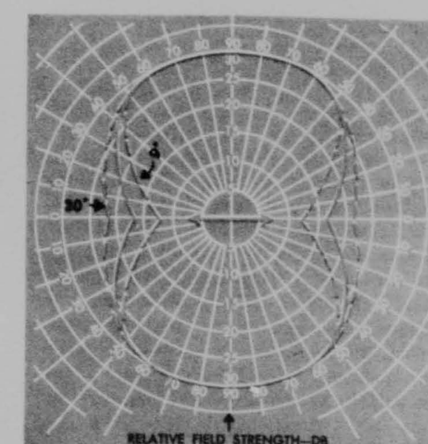


Figure 3-56 Directive Pattern of a Horizontal Half-Wavelength Antenna

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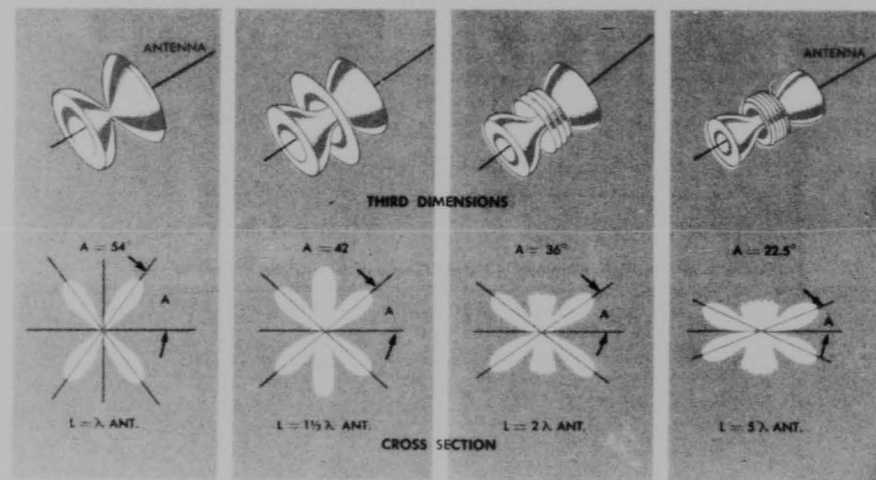


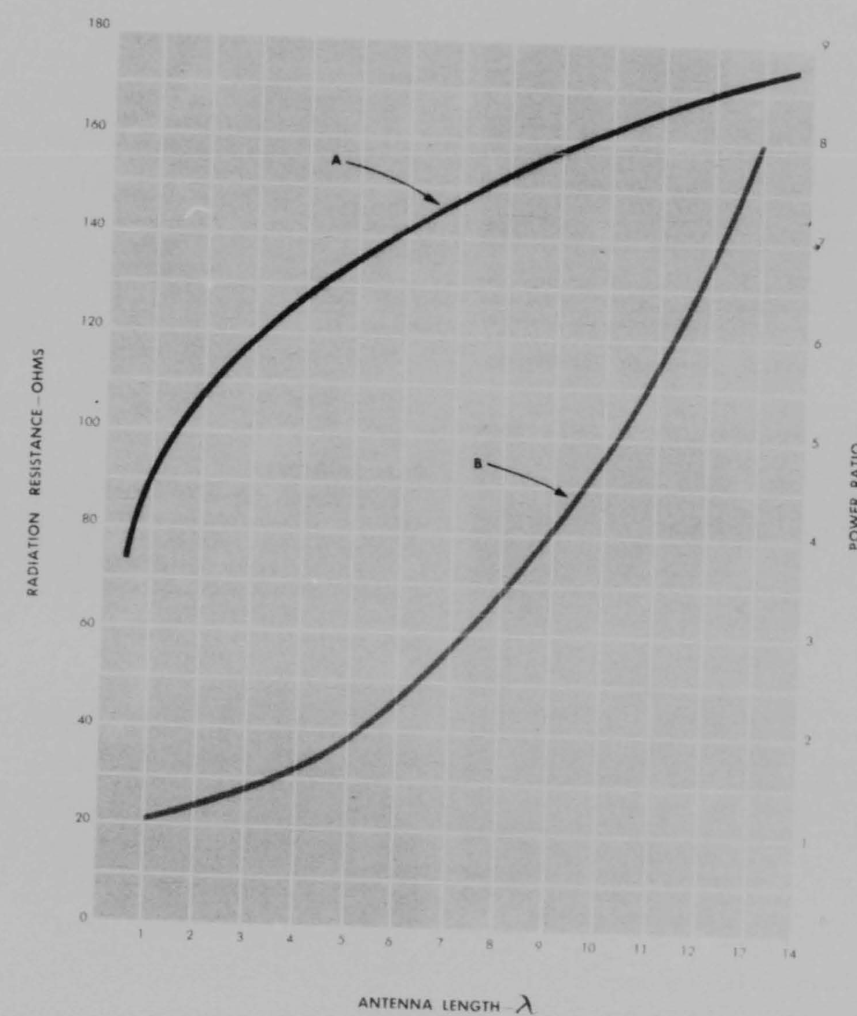
Figure 3-57 Three-Dimensional and Horizontal Cross-Section Diagram of Radiation Patterns for Long-Wire Horizontal Antenna

nant over a wide range of operating frequencies.

The directional characteristics of a nonresonant long-wire antenna differs from that of a resonant long-wire antenna in an important respect. The terminated wire is practically nondirectional, having the greatest signal gain in the direction in which the wire points, looking along the antenna toward the terminated end. The directional characteristics vary with the length of the wire, in a manner somewhat similar to the shift in directional characteristics of resonant long-wire antennas. Figure 3-60 illustrates some typical radiation patterns for rhombic antennas. It is observed that the back radiation is considerably less than the forward radiation. This condition results in a **figure eight** radiation pattern with a difference in signal intensity between the main lobes and back lobes. The free space radiation pattern of a nonresonant long-wire antenna shows directional characteristics as a result of reinforcement, or **in phase** radiation, in forward directions and cancellation, or **out of phase** radiation, in other directions.

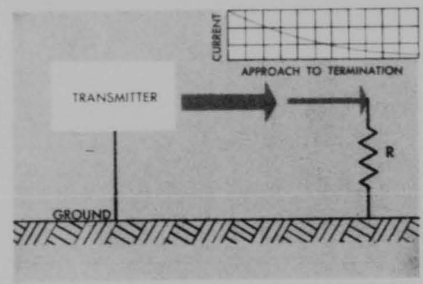
The angle which the main lobe makes with the wire depends on the antenna length, but because of the different types of current distribution, these angles are not the same for resonant (Figure 3-56) and nonresonant antennas of the same length. The difference is most marked for short wires. For a resonant one-wavelength antenna, the angle between the lobe and the wire is forty-five degrees, while the same angle for a nonresonant antenna is fifty-four degrees. However, for antennas two wavelengths or more in length the differences in this angle for resonant and nonresonant antennas is so small that it may be neglected. In the case of resonant antennas, the energy would radiate backward as well as forward. However, in nonresonant antennas the energy which would be radiated in the backward direction is absorbed by the terminating resistor. The rhombic antenna may be constructed either horizontally or vertically.

In designing a horizontal rhombic antenna which will give maximum radiation in a desired direction or maximum response to signals received from the desired direction, the wave angle (vertical angle of maximum ra-



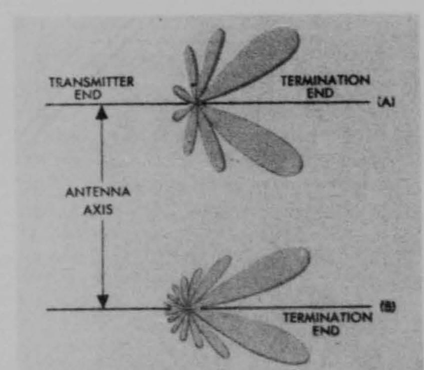
The variation in radiation resistance and power in the major lobe of long wire antennas. Curve A shows the change in radiation resistance with antenna length; curve B shows the power in the lobes of maximum radiation for long-wire antennas as a ratio to the maximum of a half-wave antenna.

Figure 3-58 Variations in Radiation Resistance and Power



This is the basis of nonresonant antenna design. The current falls off slowly from the transmitter and to the terminating resistor, but there are no standing waves.

Figure 3-59 Terminated Long Wire Antenna



Typical radiation patterns (cross section of solid figure) for terminated long wires. (A) length two wavelengths; (B) four wavelengths; both for an idealized case in which there is no decrease of current along the wire. In practice, the pattern is somewhat distorted by wire attenuation.

Figure 3-60 Typical Radiation Patterns

diation) must be first selected. Having selected the desired wave angle, the dimensions of the antenna, with the linear dimensions expressed in wavelengths, can be determined from the following formulas: (See Fig. 3-61).

$$H = 4\frac{\lambda}{4 \text{ sine } \triangle} \text{ (wavelengths)}$$

$$\sin \phi = \cos \triangle$$

$$l = \frac{1}{2 \text{ sine } \triangle} \text{ wavelengths}$$

Where:

H = antenna height in wavelengths
ϕ = angle of tilt (Figure 3-60)
l = length of each leg in wavelengths
$\triangle$ = selected wave angle

The dimensions in wavelengths may be converted to feet by the following expression:

$$\lambda = \frac{984}{f} \text{ (Feet)}$$

Where:

984 = length in feet of one wavelength at one megacycle.
f = operating frequency in megacycles
λ = wavelength.

Antenna Arrays

An antenna array is an antenna system with two or more elements arranged and energized in such a manner that the resulting radiation pattern has directional characteristics. It is beyond the scope of this text to discuss in any detail the numerous types of arrays that are possible.

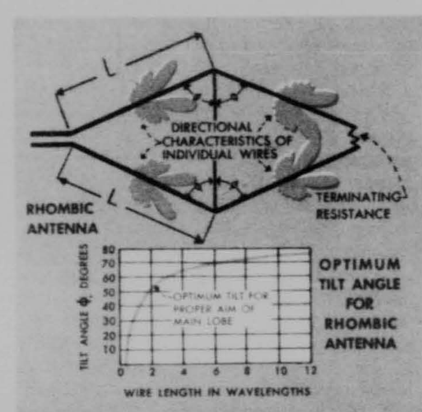


Figure 3-61 Schematic Diagram of a Rhombic Antenna Illustrating How the Optimum Wave Angle Varies With the Tilt Angle in Degrees.

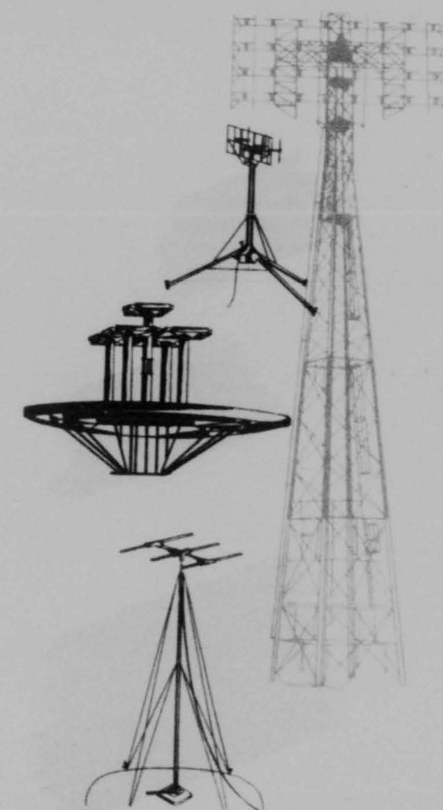


Figure 3-62 Some Typical Antenna Arrays

It is possible to obtain a very high signal gain in a favored direction or directions by employing a number of antenna elements in combinations so that the radiated signal from each of the separate elements combine in phase (reinforce) in certain favored directions and will combine out of phase (cancel) in other directions.

The resultant radiation pattern from such an array depends on the following:

The number of elements that make up the array.

The length of the elements and the geometric arrangement with respect to wavelength.

The manner in which the elements are energized.

The height of the array above the reflecting surface.

Figure 3-62 illustrates some of the many forms which antenna arrays may take.

7. FUNDAMENTALS OF RADIO WAVE PROPAGATION

General

Radio waves differ from other forms of electromagnetic radiation principally in the order of their wavelength, which ranges from about 30,000 meters to less than 1 centimeter. In general, their behavior is similar to that of light. They travel with the same velocity as light and may be reflected, refracted, or diffracted.

Radio communication is carried on by means of the radio waves which are composed of electric and magnetic fields. At the receiving antenna, the magnetic compoonent cuts it and the electric component impinges upon it, with a resultant voltage being induced in the antenna which causes a current to flow in the receiving equipment.

Larger voltages may be induced in antennas and at greater distances than those which can be transmitted over wires of reasonable dimensions. In other words, the attention in wire circuits is considerably greater than that caused by transmitting radio energy into three-dimensional space.

While the phenomena of the ionosphere and its effect on radio waves are subjects relatively unknown to man, research within the last few years has opened the doors to a new science, "frequency prediction and selection."

Frequency prediction and selection permits the communicator to take advantage of known changes in the ionosphere and to apply this knowledge in selecting proper frequencies for transmission. Likewise, a study of the behavior of the ionosphere permits adequate forecasting of the changes. As a result, poor or good transmission can be anticipated in time to make necessary adjustments in frequency selection.

For the next few years, the communicator will not be concerned with this science at the lower echelons. It is felt, however, that background knowledge of the ionosphere and wave propagation is necessary before the communications officer can understand properly the informational data on frequency prediction and selection which is sent to him monthly.

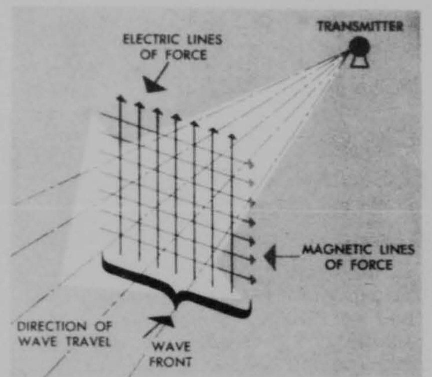


Figure 3-63 A Vertically Polarized Wave

Polarization

The electric lines of force and the magnetic lines of force are always at right angles to each other. Imagine, for instance, a latticework of horizontal and vertical strips in which the vertical strips are called the electric lines of force, then the horizontal strips will represent the magnetic lines of force. (See Fig. 3-63). The whole lattice, that is the plane containing the set of crossed lines, would represent the wave front, and the direction of wave travel is always perpendicular to the wave front.

The intensity of the waves is usually expressed in microvolts per meter, which is a measure of the dielectric stress produced by the electric field, or the voltage induced in a conductor one meter long, held at right angles to the magnetic field. While the intensity of the electric field is used to measure the strength of the radio wave, the energy contained in the wave is actually divided equally between its electric and magnetic waves.

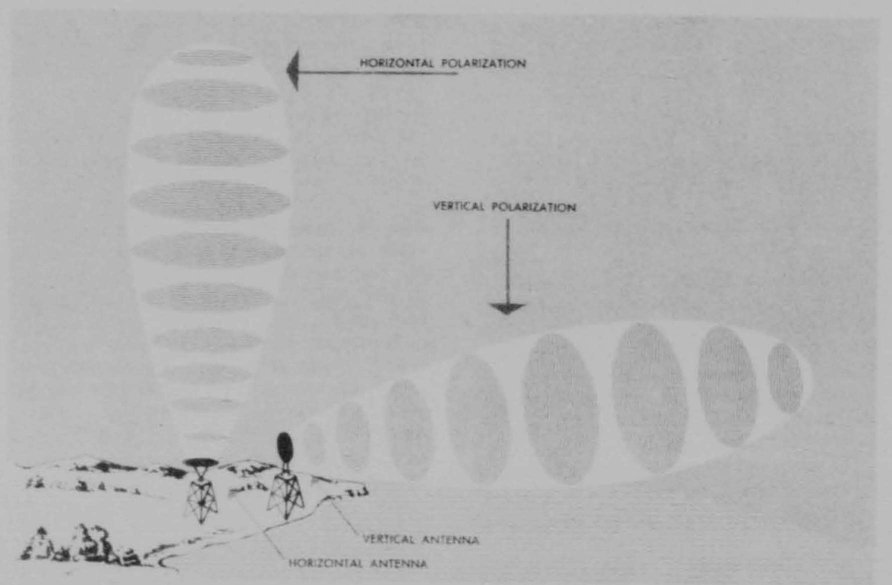


Figure 3-64 Horizontally and Vertically Polarized Waves

The polarization of a radio wave is taken as the direction of the lines of force in the electric field. If the plane of the electric field is perpendicular to the earth, the wave is said to be "vertically polarized;" if it is parallel to the earth, the wave is said to be "horizontally polarized." The electric field is parallel to the radiating antenna, therefore, a vertical antenna radiates a vertically polarized wave and a horizontal antenna radiates a horizontally polarized wave.

Horizontally polarized waves are weakened more rapidly in traveling over the ground than are vertically polarized waves. Therefore, waves of low frequency traveling along the ground usually tend toward vertical polarization regardless of antenna orientation. At high frequencies, the polarization usually varies, sometimes quite rapidly; often it is circular or elliptical because the wave splits up into several components which follow different paths.

The energy extracted from the arriving radio wave by the receiving antenna will be greatest when the antenna polarization is the same as the arriving wave. Therefore, antenna orientation (polarization) is of great importance if maximum efficiency is to be obtained from the radio equipment. Antenna orientation is most important at frequencies where sky wave transmission is involved. The polarization of the received wave seldom bears any definite relationship to the orientation of the transmitting antenna. This is due to the wave splitting up into several components which arrive at the receiving antenna by different transmission paths.

Reflection, Refraction, and Diffraction

Radio waves may be reflected, refracted, and diffracted in a manner similar to light waves. Radio waves are reflected from any sharply defined discontinuity of suitable characteristics and dimensions encountered in the medium in which they are traveling. Any conductor differing in dielectric constant from the medium through which the wave is traveling offers such a discontinuity and will cause reflection to take place if its dimensions are at least comparable to the wavelength of the radio wave. The surface of the earth, and the boundaries between dissimilar air masses in the lower atmosphere are examples of such discontinuities. Other examples of objects which cause reflection to take place if its dimensions are at least comparable to the length of the radio wave. The surface of the earth and the boundaries between dissimilar air masses in the lower atmosphere are examples of such discontinuities. Other examples of objects which cause reflection are aircraft, trees, and birds if the wavelength is small enough to be comparable to the size of the object. Radar depends upon the phenomenon of reflection for its operation.

When a beam of light passes from one medium to another, as from water to air, the path of the beam is bent. Similarly, a radio-wave is bent when it moves obliquely into any medium having a different refractive index from that of the medium which it leaves. Since the velocity of propagation differs in the two mediums, that part of the wave front which enters first travels faster or slower, depending upon the ratios of the indexes or refraction, than the part which enters last, and the wave front is turned or refracted. Radio waves travel slower as the density of the transmission medium increases. Since it requires a discontinuity in the transmitting medium to produce refraction, it is reasonable to expect that some reflection will also occur.

When a wave grazes the edge of an object in passing, it tends to be bent around that edge. This effect, called "diffraction," results in a diversion of part of the energy of those waves which normally follow a straight or line-of-sight path so that they may be received at some distance below the summit of an obstruction, or around its edges. This effect has no connection with atmospheric refraction since it occurs in a vacuum as well as the atmosphere. Figure 3-65 diagrams the reflected, refracted, and diffracted waves.

Types of Radio Waves

Radio waves may be classified according to the path along which they are propagated as **sky waves, tropospheric waves,** and **ground waves.**

The **sky wave or ionosphere wave** is that

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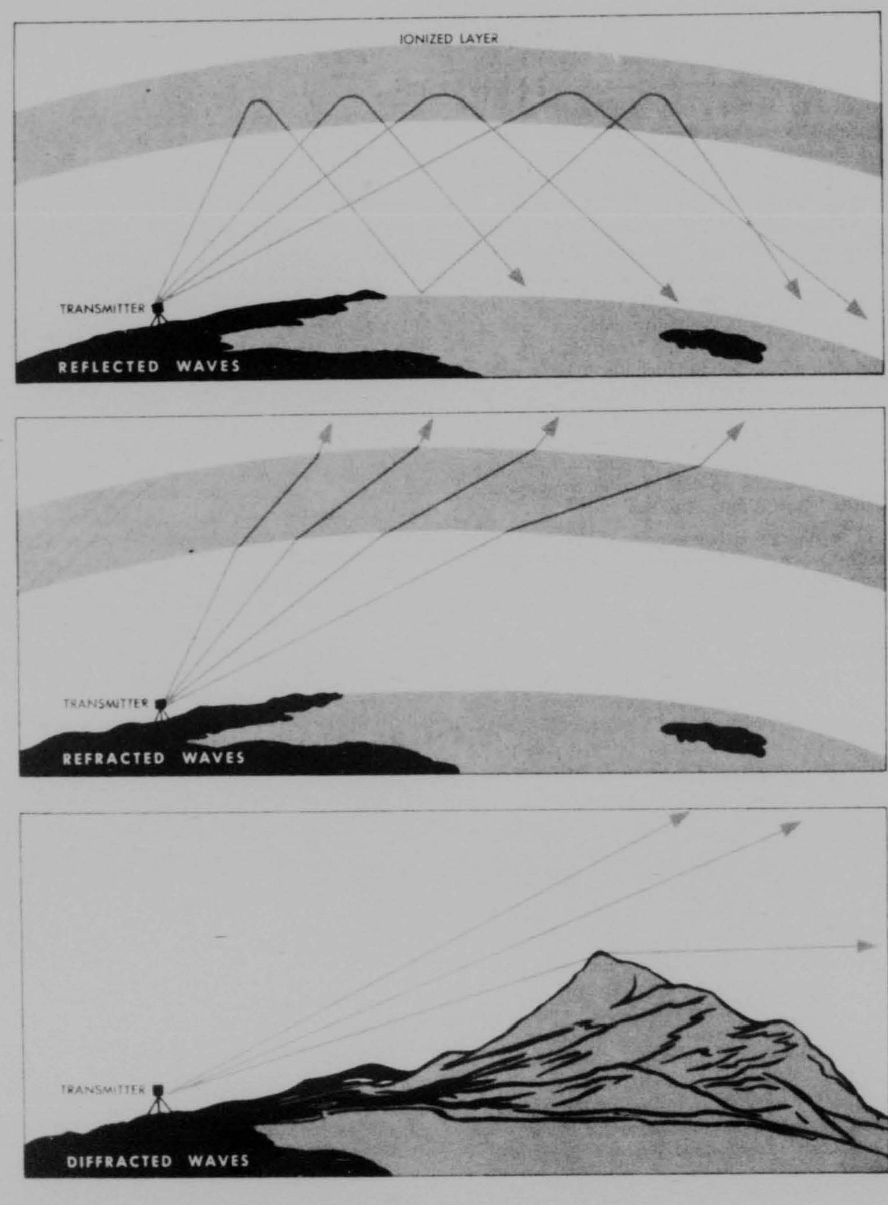


Figure 3-65 Reflected, Refracted, and Diffracted Waves

part of the radiation which is directed toward the ionosphere. Depending upon variable conditions in that region, as well as the transmitted frequency, the sky wave may be lost in space, or returned to the earth by the combined effects of reflection and refraction.

The **tropospheric wave** in that part of the total radiation which undergoes refraction and reflection in regions of abrupt changes of dielectric constant in the troposphere, such as at the boundaries between air masses of differing temperature and moisture content.

The **ground wave** is that part of the total radiation which is directly affected by the presence of the earth. The ground wave has two components. One of these is the surface wave, which is an earth-guided wave, and the other is the space wave. The space wave is the resultant of two components: the direct wave and the ground-reflected wave.

Ionospheric Propagation

The ionosphere is the upper portion of the earth's atmosphere, beginning about 30 miles, and extending to about 250 miles, above the surface of the earth, and containing layers of highly ionized air that are capable of bending or reflecting radio waves back to earth. The ionization in this region is principally due to ultraviolet radiation from the sun. The state of ionization which exists in this region would not be maintained for any length of time if it were not for the very low atmospheric pressures at the various levels concerned. Due to this, collisions between electrons and ions are relatively infrequent so the recombination to regain a normal stable state is slow. The ionization produced during the day is carried over into the night by some method which is not understood. The nighttime ionization, however, is not as strong as that observed during the day. There is a tendency for this ionization to become stratified into definite layers with each showing a maximum of ionization. For all practical purposes there are four of these layers, which are labeled, from the earth up: the D, E, F1, and F2 layers. Their average daytime heights are:

June Day

D — 30 to 55 miles
E — 55 to 85 miles
F1— 85 to 155 miles
F2—155 to 250 miles

December Day

D —30 to 55 miles
E —55 to 85 miles
F1—85 to 155 miles
F2—90 to 185 miles

The nightime F2 layer is a combination of the daytime F1 and F2 layers with a height ranging from 150 to 250 miles. This nighttime F2 layer remains relatively constant throughout the year.

While a complete understanding of the ionization phenomenon is lacking, there is sufficient knowledge to permit a fairly accurate prediction of the intensity of the ultraviolet radiation from the sun. From this knowledge, the degree of ionization in the ionosphere may be determined, and the behavior of the ionospheric radio waves may be predicted.

Although the ultraviolet light of the sun is the predominant cause of the ionosphere, certain other radiations and disturbances contribute to its formation in a somewhat lesser degree. Particle radiation is the transmission of ionized particles from solar bodies of which the sun is the principal source. Particle radiation is often associated with upheavals in the ionosphere called "storms."

The passage of meteors traveling at tremendously high speeds through the earth's atmosphere may cause local changes in the ionosphere. Such changes are predictable only in the broad statistical sense.

Little is known about the cause or nature of cosmic rays other than the fact that they have some effect on the ionosphere.

Communications between distant points by means of radio waves with frequencies between 3 and 30 mc depends principally upon the sky wave. Upon leaving the antenna, this wave travels upward from the earth's surface at such an angle that it would continue out into space were its path not bent sufficiently by the ionosphere to bring it back to earth. Each ionospheric layer consists of a central region of relatively dense ionization which tapers off in intensity both above and below.

Refraction, Reflection, Absorption. For a given density of ionization, the degree of refraction becomes less as the wavelength decreases. Therefore, the bending is less at higher frequencies than it would be for lower frequencies. If the frequency is raised to a sufficiently high value, a point is reached where the bending due to refraction becomes too small to bring one wave back to earth, even though it may enter the ionized layer along a path which makes a very small angle with the boundary of the ionosphere.

The greater the density of ionization in the ionosphere, the greater the refractive bending at any given frequency. Thus, with an increase in ionization shorter wavelengths may be bent sufficiently to permit long distance transmission. In other words, the maximum usable frequency for long distance transmission is increased.

In addition to refraction, reflection may take place at the lower boundary of an ionized layer if it is sharply defined, i.e., if there is an appreciable change in ionization within a relatively short interval of travel. For waves approaching the ionized layer at or near the perpendicular, the change in ionization must take place within a difference in height comparable to a wavelength; hence, ionospheric reflection is more apt to occur at longer wavelengths (lower frequencies).

The radio wave loses some of its energy in traveling through the ionosphere. This absorption loss increases with increasing ionospheric density. Unusually high ionization, especially in the lower strata of the ionosphere, may cause complete absorption of the wave energy. Nearly all of the absorption is the result of the wave entering and leaving the ionosphere.

Virtual Height. Although the ionospheric layer is a region of considerable depth, it is convenient to assign it a definite height, called the "virtual height." The virtual height is the height from which a simple reflection would give the same effect as the gradual bending which actually takes place. The wave follows the path **TBR** (Figure 3-66). It is noted that the bending takes place over a considerable distance and consumes a measurable period of time. The virtual height is the height of the triangle **TAR**. It is calculated on the basis of the angles at which the wave leaves and returns to the earth. The time required for a wave traveling with the speed of light to travel the path **TAR** is the same as that required by

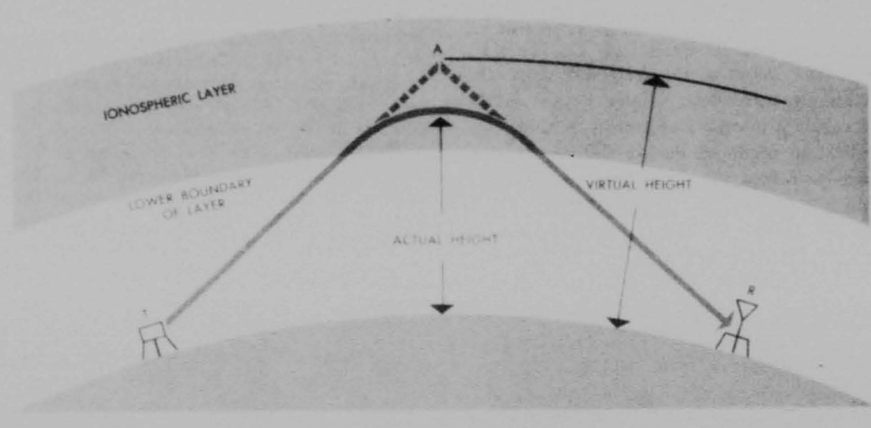
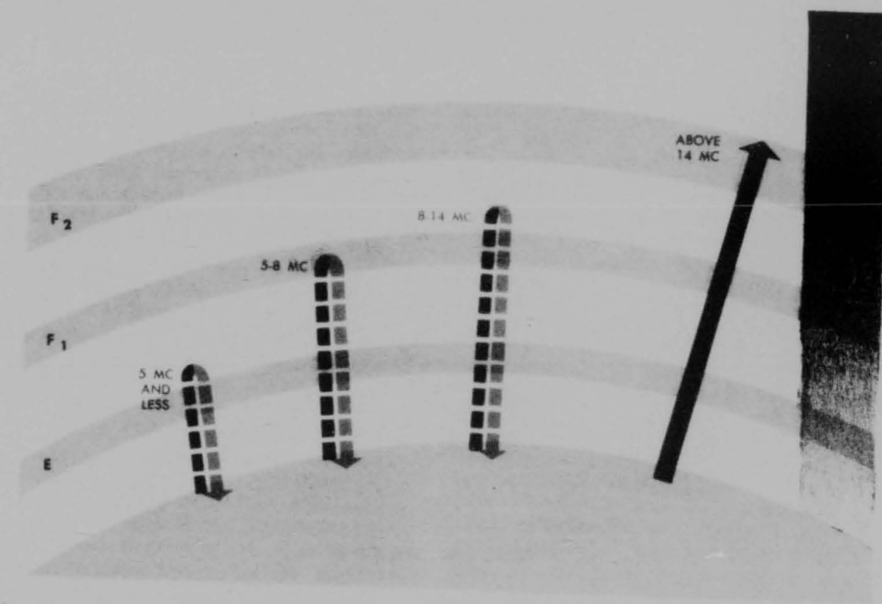


Figure 3-66 Virtual Height



The highest frequency that will be reflected from a layer in a vertical path is the critical frequency for that layer.

Figure 3-67 Refraction Chart

the radio wave to travel the path **TBR**. Although the path **TBR** is shorter, the velocity of the radio wave is sufficiently reduced in the ionosphere to make up for the shorter distance.

Critical Frequency. When the frequency is sufficiently low, a wave sent vertically upward will be bent sharply enough to be returned to the starting point. The highest frequency at which such reflection can occur, for a given state of ionization of the ionospheric layers, is called the "critical frequency" for that layer. Figure 3-67 indicates the approximate critical frequencies that may be expected for E, F1 and F2 layers. Although the critical frequency may serve as an index of transmission conditions, it is not the maximum usable frequency, since other waves which enter the ionosphere at angles smaller than 90 degrees (less than vertical) will be bent sufficiently to return to the earth. The maximum usable frequency for waves leaving the earth at very small angles to the horizon is approximately three times the critical frequency. Besides being directly observable, the critical frequency is of more practical interest than the ionization because it includes the effects of absorption as well as refraction.

Maximum Usable Frequency. Radio waves shot vertically into the ionosphere (i.e., at vertical incident) are refracted almost vertically. These signals are returned to the earth in the vicinity of the transmitting antenna and hence have only limited application since we are interested more often in long distance radio communication. If the frequency of the radio wave exceeds the value of the critical frequency, the wave punches through the ionosphere and is lost into space. Waves A in Figure 3-68 represent a group of such waves.

To traverse the long distance often required in radio communication, the radio

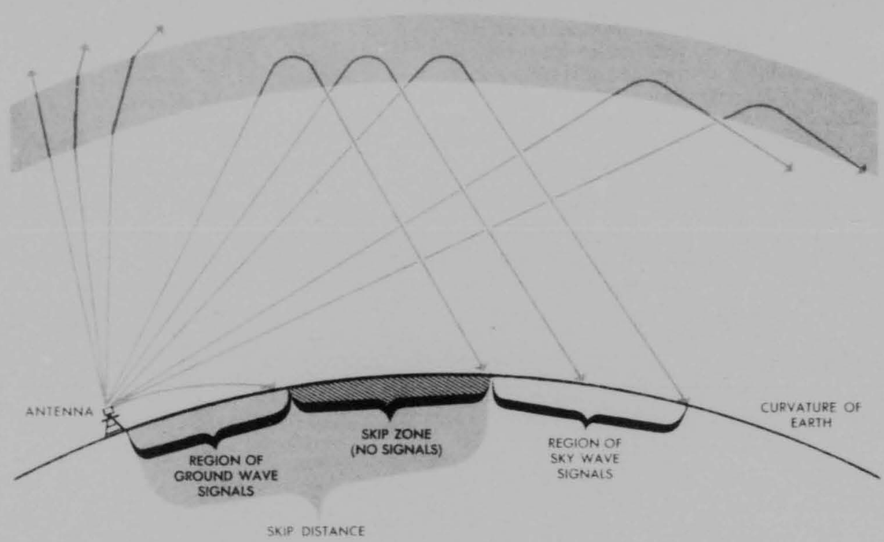
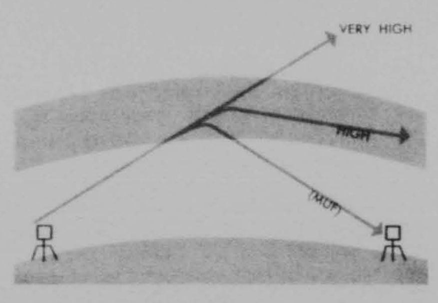


Figure 3-68 Skip Zone

wave must enter the ionosphere at oblique angles, the exact value of which depends on the height of the layer and length of the transmission path. It will be observed that as the transmission distance increases, the grazing angle (the angle at which the wave enters the ionosphere) becomes smaller; until, at long distances, the signal path grazes the ionosphere at a very small angle. As the grazing angle becomes smaller, radio waves of higher frequency will be returned to the earth since less refractive bending is necessary to change the direction of the wave. At angles approaching vertical incidence, the path of the wave must be nearly 180 degrees to be returned to the earth. It is readily seen that a definite relationship may be established between the length of the transmission path and the highest frequency that will traverse the path. The highest frequency that can be used for a given path is called the maximum usable frequency (MUF). Frequencies above the MUF will either be lost in space, or will be returned to the earth at a more distance point. Frequencies excessively below the MUF are generally unsatisfactory, due to absorption and natural atmospheric noise.

Since greater bending is required to return the wave to earth when the angle of incidence is large, the refraction at high frequencies may not be sufficient to produce the required bending. Therefore, the angle of incidence must be smaller than a certain angle, known as the "critical angle," in order to produce sufficient bending to return the wave to the earth. The distance (determined by the critical angle) between the transmitting antenna and the receiving antenna is the shortest possible distance over which communications by normal ionospheric refraction can be accomplished.

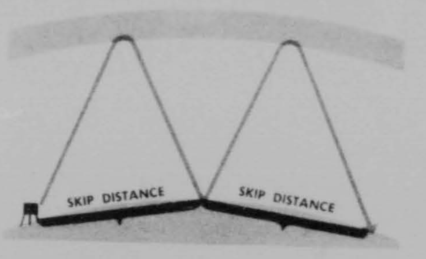


Skip Zone. The area between the end of the useful ground wave and the beginning of the sky wave reception is called the "skip zone." The extent of the skip zone depends upon the frequency employed and the state of the ionosphere. The higher the radio frequency employed, the greater the extent of the skip zone increases. For a given frequency and critical angle, the extent of the skip zone will vary with the height of the layer in which the refraction takes place.

The "skip distance" may be defined as the distance from the transmitting antenna to the point of first ground reflection or the distance between successive ground reflections. It is easily seen that the skip distance varies under the same conditions as the skip zone. (Figure 3-68)

Normally, the wave angles at the transmitting and receiving points are approximately the same for any given transmission path. It is readily possible for the ionospheric wave to pass through the E layer and be refracted back to earth by the F1 or F2 layer, as the critical frequencies are higher in these layers. Depending on the wave angle, frequency, and ionospheric conditions, it is sometimes possible to carry on communication via either the E, F, or F2 layers on the same frequency.

Optimum Working Frequency. The maximum usable frequency could be utilized for communications were it not for the fact that it contains no safety factor to take care of small unpredictable changes in the ionosphere. For example, a decrease in the intensity of the layer could cause the signal to not be returned to earth since MUF involves a critical frequency at a critical angle.



The MUF is considered to be reliable 50 per cent of the time. As the frequency of a wave is decreased there is an increase in the probability of the wave being refracted to earth. It is possible to achieve a reliability of 90 per cent by selecting a slightly lower frequency. This lower frequency is called the optimum working frequency (OWF) and its values are established by the following relationships:

F1 and E layers	OWF—MUF $\times$ 0.97
F2 layer	OWF—MUF $\times$ 0.85

It is observed that little correction is required for the E and F1 layers. This is due to the random variation in the ionosphere being confined mostly to the F2 layer.

Lowest Useful High Frequency. The optimum working frequency is the highest radio frequency that can be used for reliable communication along a given transmission path. However, to meet all the communications requirements of military situations, frequencies other than the OWF must be used. Since we know that, for a given transmission path, frequencies above the OWF cannot be relied upon for constant communication, the selection of additional frequencies must be made from those below the OWF. The problem here is to find how far below the OWF we may expect reliable communication. This lower limit is known as the lowest useful high frequency (LUHF).

A number of factors establish the LUHF, and its determination is usually the most difficult problem in frequency prediction. Some of the factors are:

Ionospheric absorption causes the radio wave to lose some of its energy as it passes through the ionospheric layers. This effect is greatest in the lower layers of the ionosphere.

Atmospheric or man-made noise in the vicinity of the receiver are important factors in establishing the LUHF. Most atmospheric noise is generated in tropical areas, mountains, and desert areas. The noise factor must be taken into account particularly in the design of highly directional antennas since such antennas may defeat their intended purpose should they beam the radio wave along a portion of the great circle path which passes through a zone of high atmo-

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spheric noise. In such cases a reciprocal path may be more satisfactory.

Radiated power of the antenna is another factor which must be considered in establishing the LUHF. As the upper limit of the high frequency band is approached, the atmospheric noise intensity decreases which permits the reception of weaker signals. However, toward the lower limits of the high frequency band the atmospheric noise intensity increases and requires that the signal intensity be greater so that reception may take place. For a given distance, the strength of the signal at the receiving point will be determined by the power radiated at the transmitting antenna. In other words, to increase the strength of the received signal, the power radiated by the transmitting antenna must be increased. The power radiated by the transmitting antenna should not be assumed to be the same as the power rating of the transmitter. It is not uncommon to have a transmitter with a high power rating, only a fraction of which is radiated by the antenna.

Radio waves are similar to light waves in that their intensity varies inversely with the square of the distance from the source. Therefore, if the transmission path is excessively long for a given radiated power, the signal may be too weak at the reception point to permit detection.

The skill or ability of the radio operator to reach weak signals is the least predictable of the factors which establish the LUHF, but it is sometimes the determining factor. It is well known that continuous wave signals may be received more easily than voice signals. One agency maintains that fifty times more signal strength is required for voice signals than for continuous wave signals. It is possible under unusual circumstances for the LUHF to have a higher value than the MUF.

Predictable Ionospheric Variations. Since the ionosphere exists primarily because of the ultraviolet radiation of the sun, it is evident that any variation in the strength of this radiation will cause a corresponding change in the make-up of the ionosphere. Some of the variations are periodic and their effects on radio frequencies may be anticipated. Others are unpredictable and while their effects are pronounced, there is little that can be done at the present time except to realize that they may occur. There are three types of normal variations: daily, seasonal, and sunspot.

The twenty-four hour rotation of the earth about its axis causes not only a variation in intensity of the visual light, but also a corresponding variation to the intensity of the ultraviolet radiation that passes through the ionosphere.

During the day, the ionosphere consists of four ionized layers. At night, however, only one weakly ionized layer exists; it is known as the "nighttime F2 layer." The nighttime F2 layer is formed by a combination of the daytime F1 and F2 layers which merge just inside the night area. If the same frequency is used for night transmission as for day transmission, the signal will force its way through the weakly ionized nighttime F2 layer. The critical frequency of the nighttime F2 layer, therefore, is lower than in the daytime. Consequently, the nighttime transmission frequencies must be lower than those employed in the daytime.

The seasonal variation in the ionosphere is due to the change in intensity of the ultraviolet light reaching the earth's atmosphere as the earth moves in its orbit around the sun. The earth is nearer the sun in December than in June; therefore, the ultraviolet light is more intense in December. This results in a more highly ionized ionosphere and higher critical frequencies in December than in June.

The third predictable variation is that of the sunspot cycle variation. Sunspots are so named because they resemble spots or craters when viewed through a telescope. Their cause is still obscure, but it has been ascertained that their number and intensity vary through a complete cycle, i.e., from maximum to maximum, within a period of nine to thirteen years, the normal period being eleven years. The ultraviolet radiation is more intense at a sunspot maximum than at a sunspot minimum.

Unpredictable Ionospheric Variations. The

unpredictable ionospheric variations are ionospheric storms and "sporadic E," (see definition below.)

An ionospheric storm is any marked or sudden deviation from normal conditions of layer height or critical frequency. Such storms may last for a few minutes or for several weeks and have a tendency to repeat every twenty-seven days, coinciding with the period of solar rotation. Some evidence tends to correlate these storms with solar activity. Ionospheric storms are most prevalent during unusually violent sunspot activity, when gigantic eruptions may be observed on the surface of the sun. The effects of ionospheric storms are most noticeable in the **auroral zones** (belts entering roughly around the north and south geomagnetic poles of the earth). During these storms, a normally reliable frequency may become unworkable and radio signals may weaken or disappear entirely. It is believed that these unusual disruptions of communications are caused by a tremendous increase in ultraviolet radiation of the sun, brought about by the eruptions on its surface. This strong ultraviolet radiation saturates the ionosphere to such an extent that radio signals are obsorbed rather than returned to the earth.

Another unusual condition that affects radio communication is **sporadic E.** Sporadic E consists of intensely ionized patches or clouds lying within the E layer of the ionosphere. The ionization in these patches is considerably above the ionization normally expected in this layer. It is not readily predictable, and therefore cannot be relied upon for dependable communication. It has been found to be more prevalent, however, during the early spring months in the northern latitudes. The greatest effect of sporadic E is to permit abnormally long distance transmission of VHF radio signals, sometimes as far as 1,500 miles. It may cause errors of 180 degrees in the signal path. This will be of great importance to the VHF direction finding and homing stations if sporadic E transmission is encountered during their employment.

Single and Multi-Hop Transmission. Since there is a definite limit to the heights of the layers, it may be shown geometrically

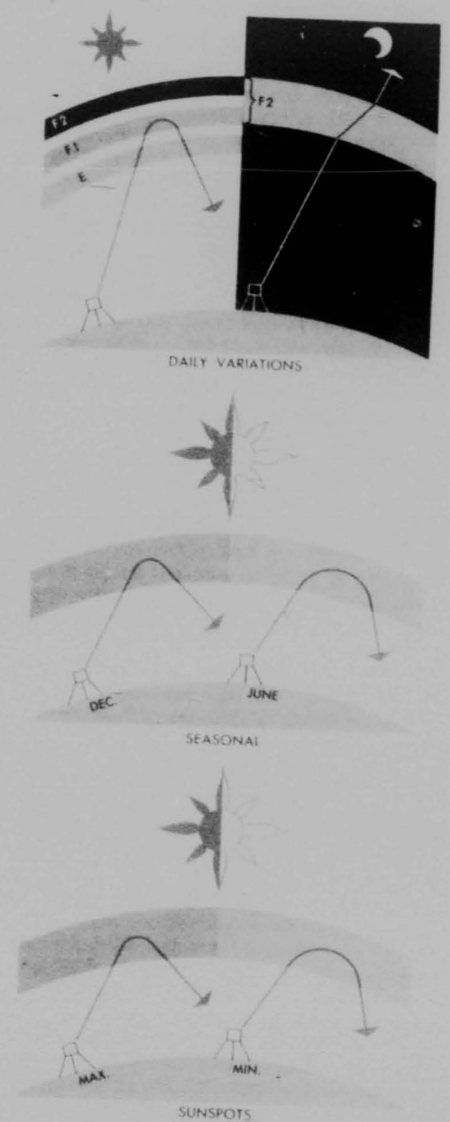

Figure 3-69 Predictable Ionospheric Variations

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that there is also a limit to the distance along the earth's surface over which a sky wave can pass in one "bounce." For the F2 layer this maximum distance is 2,500 miles, for the E layer, 1,250 miles. When the distance between the two ends of the transmission path is equal to, or less than, the maximum distance, the signal will traverse that distance in one bounce. This is known as single-hop transmissions. When the transmission path is greater than the maximum distance more than one bounce is required for the signal to be bounced, or refracted, back to earth. The point at which the reflection from the earth takes place is called the control point. In single-hop transmission, there is only one control point which is located at the midpoint of the transmission path. In multi-hop transmission, the signal may bounce between the earth and the ionosphere many times before reaching the end of its transmission path. This introduces the interesting possibility of many control points. However, in actual practice it is necessary to establish only two control points. These control points are located 1,250 miles from each end of the transmission path. It is the condition of the ionosphere at these control points which determines the maximum usable frequency for any transmission.

Fading. Two or more parts of a wave may follow slightly different paths in traveling to the receiving point, in which case the difference in path lengths will cause a phase difference to exist between the wave components at the receiving antenna. The field strength, therefore, may have any value between the numerical sum of the components (when they are all in phase) and a zero (when there are only two components and they are exactly out of phase). Since the paths change from time to time, this causes a variation in signal strength called fading. Fading also can result from the combination of single-hop and multi-hop waves, or the combination of a ground wave with a sky, or tropospheric, wave. Such a condition gives rise to an area of severe fading near the limiting distance of the ground wave with better reception being obtained at both longer and shorter distances where one component is considerably stronger. Fading may be rapid or slow, the former type resulting from rapidly changing conditions in the ionosphere, the latter occurring when transmission conditions are relatively stable.

It frequently occurs that transmission conditions are different for waves of slightly different frequencies, so that in the case of voice-modulated transmission, involving frequencies differing slightly from the carrier in frequency, the carrier and various side band components may not be propagated in the same relative amplitudes and phases they had in the transmitter. This effect, known as "selective fading," causes severe distortion of the signals, especially in the case of frequency-modulated signals received over other than line-of-sight paths. The distortion results from the fact that the instantaneous frequency of the FM signal is subject to continual variation, so that when two waves reach a receiving antenna by different paths, they differ in instantaneous frequency. The result is a combined wave in which components of both amplitude, and frequency modulation make up a new modulation at a frequency which is not harmonically related to the modulation impressed at the transmitter, but which depends upon the differences in transit time for the different paths traveled by the waves. The resulting distortion is greatest at high modulation frequencies and with high depths of modulation.

Tropospheric Propagation

The troposphere is that part of the earth's atmosphere occupying a space above the surface of the earth to a height of about six miles in which temperature generally decreases with altitude, clouds form, and convection is active. Variations in coverage of radio and radar equipment are caused by atmospheric factors which are in the troposphere. The influence of these factors are most noticeable in the VHF, UHF, and SHF bands.

The rapid and accurate evaluation of radio and radar signals is dependent to a great extent upon our knowledge and understanding of the effects produced by the variable conditions of the lower atmosphere.

U.S. warships in the Pacific, in several instances, have picked up targets by radar

at distances four or five times greater than those obtained under normal conditions. Enemy ships far beyond the horizon have been located and sunk by radar controlled gunfire. On some occasions, military coastal radars have tracked convoys twenty to thirty miles beyond normal radar ranges. Yet, a few hours later, these same radars have failed to detect targets clearly visible to the eye. While these conditions are unusual, they do occur frequently enough to cause considerable concern to the communications officer for he must be able to explain these unusual conditions and interpret them in any tactical situation that may occur. Serious errors and false evaluation of radar presentation, as well as VHF radio transmission may result, if the communications officer does not take into consideration the effects of weather and atmospheric conditions on radar ranges and VHF coverage.

The unusual conditions, which are caused by nonstandard atmosphere, might leave doubt as to the effectiveness of radar and VHF radio. However, understanding and allowing for these phenomena will make a useful instrument more effective, will make the weather work for, instead of against, radar and radio equipment.

These unusual ranges are caused by bending or refraction of the radio waves in the atmosphere. An important special case of refraction is the concentration of the wave energy in ducts within the atmosphere. The bending and duct formation is a direct result of the meterological factors involved and in many cases is peculiar to the locality and season. These factors will be discussed later.

Bending. It is usually assumed that VHF, UHF, and SHF radio waves travel along the line-of-sight from the transmitter to the receiver, and, in the case of radar, to and from the target. Experience has shown that this assumption, nearly true in many instances, may lead to serious errors or false evaluation if the meteorological conditions vary from those upon which the assumption is based.

Radio waves are bent from a straight line path as a result of refraction by the lower atmosphere. This bending, or refraction, is generally recognized as a property of light. It is equally a property of radio waves. The underlying principles are exactly the same.

The quality that determines refraction is called the index of refraction. Refraction occurs whenever there is a change of index of refraction, as at the boundary of two substances. In the interior of a homogeneous material, the index of refraction is constant and the rays travel in a straight line. The greater the difference in the index of refraction between two materials, the greater will be the change in the direction of the ray's travel.

Radio waves are refracted or bent in the atmosphere since the index of refraction changes with height. The properties of the atmosphere which determine the index of refraction and which change the height are temperature, pressure, and moisture content. These changes from one level to another are very small when compared to the change between that of water and air, and the resulting refraction is very small. Nevertheless, this refraction is of great importance in radar operations and radio communications at frequencies about thirty megacycles. It is only the exceptional case which permits communications to be carried on by means of the ionosphere, and, as already pointed out, these cases are unpredictable and, therefore, unreliable. The principal means of transmission at frequencies above thirty megacycles is the troposphere.

If the atmosphere were composed of a number of successive layers each having a different index of refraction, a wave passing across successive boundaries would encounter an abrupt change in direction at each boundary surface. However, the atmosphere does not exist in distinct layers, but, in such a state that the changes in its physical properties and index of refraction are gradually, but continuously, changing. Therefore, there is no sudden change in the direction of the wave, but a continuous gradual change in direction as the waves pass through the atmosphere. Radio waves passing through the lower atmosphere are normally bent downward.

Figure 3-70 illustrates the actual vertical pattern of a radar set. It is observed that the radio line-of-sight is somewhat greater

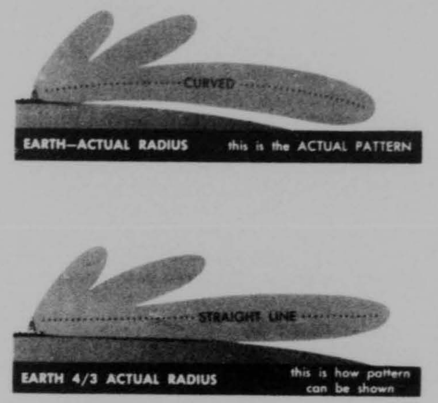

Figure 3-70 Radar Lobe Patterns

than the optical line-of-sight. This is due to the refraction of the radio waves by the atmosphere. Under average weather conditions, the horizon distance is increased approximately 15 per cent. However, at low elevations in the vicinity of the first lobe, the range increases will not be this great. The vertical dimensions in Figure 3-70 have been greatly exaggerated so that the earth's curvature becomes clearly visible. This figure depicts normal or standard propagation.

It is inconvenient to draw curved rays in constructing radar coverage and calibration diagrams. It would be very convenient if the radius of the earth could be increased to some fictitious value that would compensate for the refractive bending of the radio waves under standard conditions and permit the radio waves to be treated as if they traveled in straight lines. Analysis of the normal atmospheric conditions and the associated refraction has shown that if the earth's radius is increased by a factor of 4/3 this situation will exist. Figure 3-70 illustrates the lobe as it may be plotted using the radius of the earth as 4/3 of its true value.

Wave propagation will deviate from the norm under special weather conditions and is called "guided propagation," "trapping," or "super refraction"—sometimes referred to as "anamalous propagation." The principal feature of this type of propagation is an excessive bending of the radio waves due to refraction. This bending occurs principally in the lower portion of the atmosphere and mainly in the lowest few hundred feet. However, in certain regions, notably the warmer climates, excessive bending has been observed as high as 5,000 feet. The amount of bending in regions above this height is normally that of standard atmosphere. Figure 3-71 illustrates the normal radar pattern under normal atmospheric conditions. Figure 3-72 illustrates the shape that a radar pattern may assume under nonstandard atmospheric conditions.

The fact that atmospheric influences are effective only in the lower layers does not imply that the signal strength from the target will be affected only if it is in these layers. The greatest effects will be observed in the lower portions of the coverage pattern although variations in the pattern may be expected to extend to considerable heights. The excessive bending is suffered by the rays only while passing through the lower layers.

Two factors are operative in producing a rapid change of the index of refraction with height. They are variation of moisture with height and variation of temperature with height. Excessive refraction occurs when there is a rapid decrease of moisture with height **(moisture lapse)** and, to a lesser degree, when there is a rapid decrease in temperature with height **(temperature inversion)**. The most pronounced cases of excessive refraction occur when both of these conditions prevail, simultaneously. These conditions will be discussed later from the meteorological viewpoint.

Since the atmosphere is a very tenuous substance, the amount of refraction is very small and in no case exceeds a fraction of a degree. How then can these small effects influence radar operations? The answer is that they do not influence operations unless the angle between the wave path and the horizontal is very small. If a radar is used for fire control, search-light control, or ground-controlled interception, the targets are usually at medium or short ranges, and the angle between the line-of-sight to the target and the horizontal is usually greater

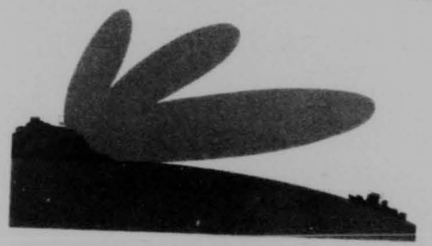

Figure 3-71 Radar Lobe Patterns in Standard Atmosphere

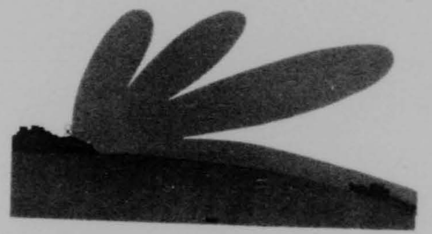

Figure 3-72 Radar Lobe Patterns in Nonstandard Atmosphere with Duct Formed

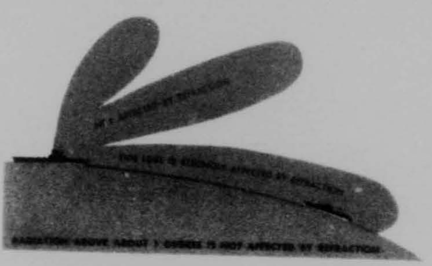

Figure 3-73 Refraction of Radar Lobes

than one or two degrees. Refraction has practically no effect on such radar applications. Figure 3-73 illustrates this point. Note that the height scale is greatly exaggerated in comparison to the range scale.

The same equipment, however, may be used for long-range search and then the picture is different. With long-range search radar the target may be an aircraft fifty or a hundred miles away, and flying at an elevation of a few thousand feet. In this case, the angle of elevation of the target above the horizontal, as seen from the radar, is only a fraction of a degree. The angle of elevation decreases as the elevation of the target decreases until the limiting condition of seaborne targets is reached. Thus, in this case, the atmospheric effects become operationally important. It must be kept in mind that only low-angle search is affected by meteorological conditions.

As a general rule, the operational characteristics of a radar observing targets with elevation angles exceeding one degree may be calculated on the assumption of a standard atmosphere, with confidence that all nonstandard meteorological effects are negligible.

Guided Propagation. Radio signals may be guided through the atmosphere much in the same manner as in waveguides if the proper atmospheric conditions are present. Within the duct there is less decrease of signal strength with distance than there is above the duct: (The waveguide in space is called a "duct.") Radar ranges on surface craft and low-flying aircraft located within a duct, similar to the one illustrated in Figure 3-72, are increased sometimes to two, three, or four times the normal ranges. Ground echoes will be increased at the same time and might partly or entirely obscure the echoes from the incoming aircraft. While this additional range is very desirable, operational procedures are rarely set up to take advantage of this condition since it is difficult to predict its occurrence and impossible to control.

In Figure 3-74, wave paths are illustrated as rays.

Ray No. 1 is bent so much that after some distance it returns to the ground; there it is reflected and then the same course is repeated. In this way, the ray may be reflected a number of times in succession, remaining always in the lowest layer. This superrefraction **traps** the rays in a **duct**, and results in guided propagation of the radar waves. Trapping does not occur under standard atmospheric conditions. A ray, under normal conditions, may be reflected by the earth's surface only once before it escapes into space.

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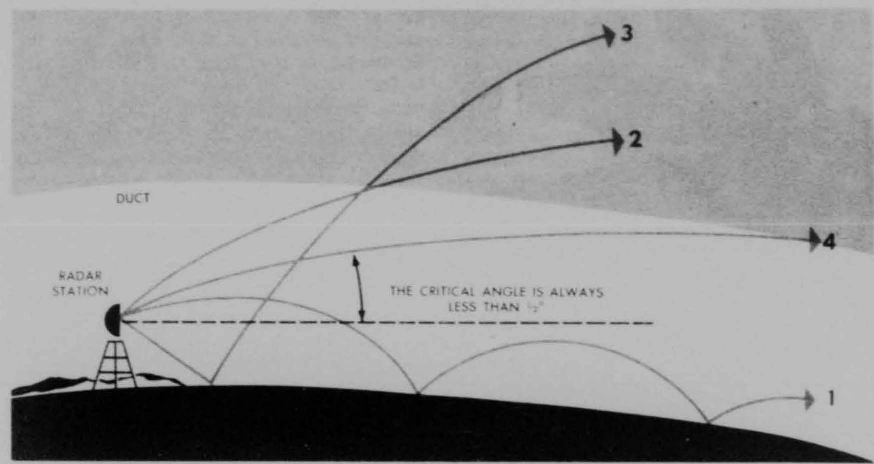

Figure 3-74 Guided Propagation

Ray No. 2 is also bent in the lowest layer, but not enough to keep it from escaping into the upper atmosphere whence it does not return to earth.

Ray No. 3 is similar to No. 2 except that it undergoes one reflection by the ground before it escapes into the upper atmosphere.

Ray No. 4 separates the two types of rays illustrated by rays 1 and 2. This ray becomes horizontal when it reaches the top of the trapping layer, or duct, and from there on travels along the same height. All rays are divided into two groups: those that leave the transmitter at an angle with the horizontal less than the critical angle and are trapped, and those that leave the transmitter at a larger angle and proceed into the upper atmosphere.

The critical angle is always small, practically never larger than ½°. Its magnitude may be taken as a measure of the intensity of guided propagation, that is, of the amount of radiation energy trapped within the duct. Rays that leave the transmitter at a somewhat larger angle are sufficiently deflected while passing through the lowest layers to distort that part of the radar coverage pattern lying just about the duct. Rays leaving the transmitter at a still larger angle are not appreciably affected.

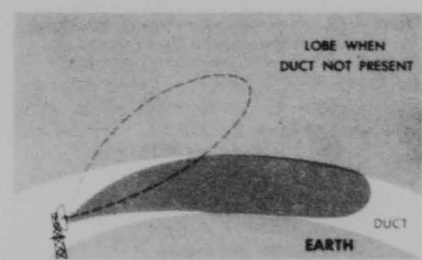

Figure 3-75 Ground-Based Duct

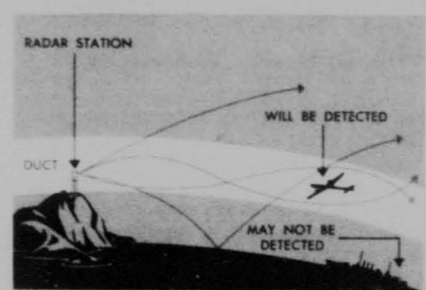

Figure 3-76 Elevated Duct

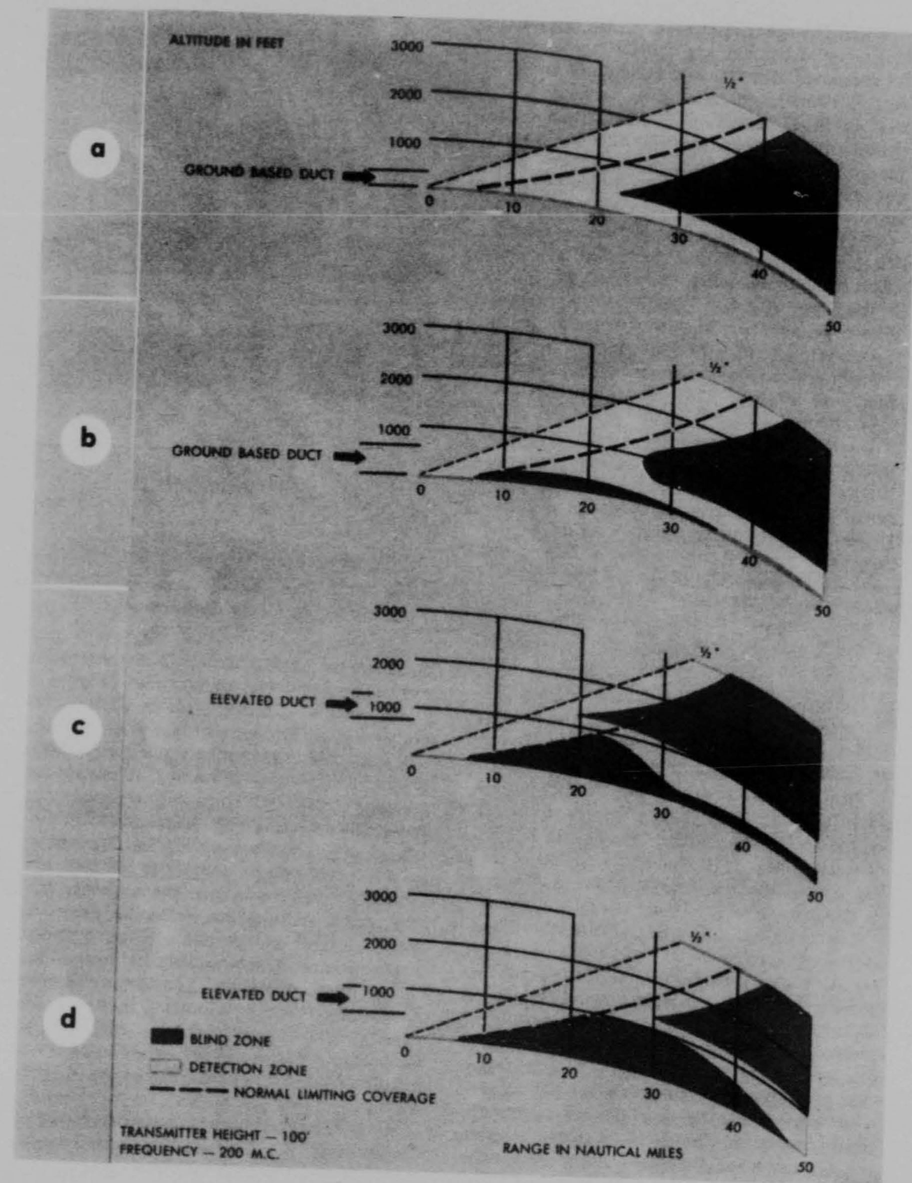

Figure 3-77 Deformation of Lower Lobes

When the radar is located within the duct, ranges on aircraft flying above the duct may be decreased slightly, and frequently the effective range may be slightly increased. If the angle of elevation of the aircraft is greater than one degree, the effects become inappreciable and failure to detect the target cannot be attributed to excessive refraction.

The guided propagation is noticed in the VHF, UHF, and SHF bands. The greatest effect is observed when the wavelengths are in the order of a few centimeters. However, guided propagation has been reported with wavelengths up to one and one-half meters.

Figure 3-75 illustrates the ground-based duct and Figure 3-76 illustrates the elevated duct.

Interference between the direct rays and the rays reflected from the ground, resulting in the well known lobe pattern of the coverage diagram, have not been mentioned. Under standard atmospheric conditions the position of the lobes depend only on the wavelength and the height of the antenna above the ground.

When a duct is present, the lowest part of the coverage diagram may be strongly distorted as is illustrated in Figure 3-77.

Meteorological Factors. In the troposphere the atmosphere is responsible for the normal and abnormal bending of the radio waves. In order to understand this phenomenon, it is necessary to consider the meteorological factors involved.

The refractive index of the atmosphere is defined as the "ratio of the velocity of radio propagation in vacuum to the velocity in the atmosphere." Under standard atmospheric conditions, there is a normal index of refraction which decreases gradually as the altitude is increased. Nonstandard atmosphere has an index of refraction which decreases gradually as the altitude is increased. Nonstandard atmosphere has an index of refraction which is different from that of standard atmosphere and which decreases more rapidly than normal as the altitude increases. The decrease depends upon the distribution of moisture and temperature in the atmosphere, particularly in the lowest few hundred or thousand feet.

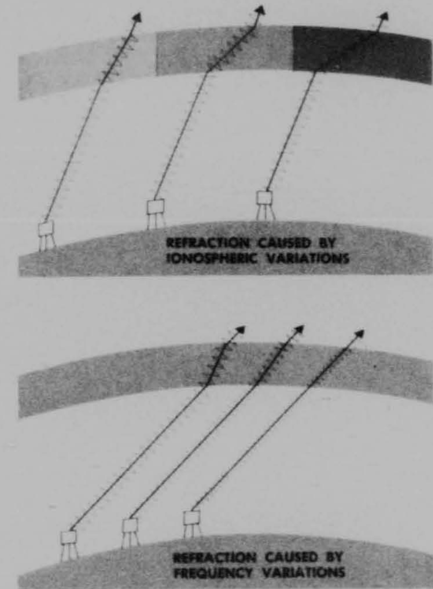

Figure 3-78 Refraction

Normally, the atmospheric temperature decreases at approximately 2 degrees centigrade per 1,000 feet of altitude. (Figure 3-79A). However, under some conditions, the air temperature may increase with altitude. Figure 3-79A shows a normal temperature gradient. Figures 3-79B and C illustrate two temperature distributions known as temperature inversions.

The moisture content of the atmosphere behaves in a manner similar to temperature. Under normal conditions, the moisture content of the atmosphere gradually decreases with increasing altitude. (Figure 3-80A shows normal moisture distribution.) When the moisture content of the atmosphere behaves other than in a normal manner, it is called a "moisture lapse." (Figure 3-80B and C illustrate two possible ways the moisture content of the atmosphere may be distributed.)

A moderate or strong moisture lapse almost always will produce the wave trapping which is necessary for guided propagation, while a temperature inversion will lead to trapping only if the moisture distribution

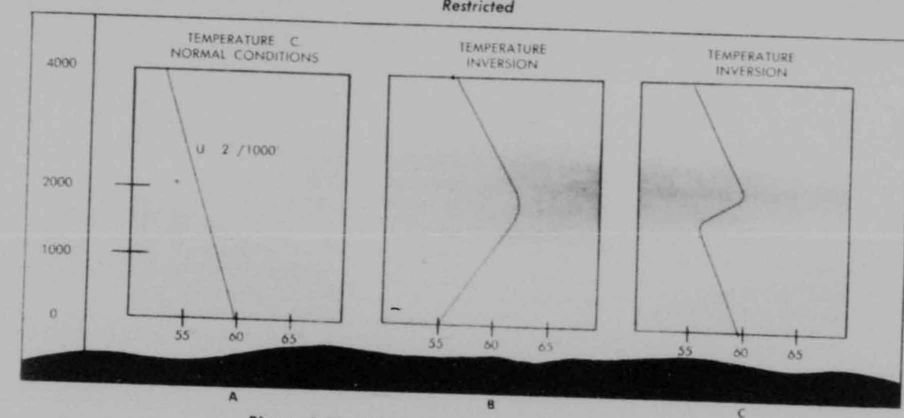

Figure 3-79 Atmospheric Temperature Distribution

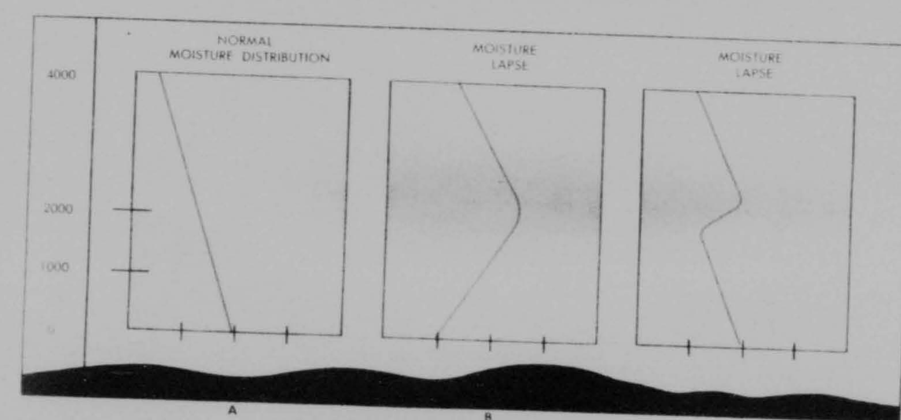

Figure 3-80 Atmospheric Moisture Distribution

is favorable. However, a combination of a moisture lapse and a temperature inversion within the same layer will usually produce trapping. This weather condition is one of the most common causes of guided propagation. An example in point is the Mediterranean, which to the south, east, and west is surrounded by dry land masses which produce a flow of dry, warm air over the water when the winds are blowing from land to sea across the eastern boundary of a continent. Land and sea breezes may influence radar operation across a coast line. The wind direction at a coast is often an important factor in determining propagation conditions and should be closely observed. Whenever unusual propagation is detected by coastal radar stations, a record of prevailing winds at the time is very helpful in the determination of anticipated performance.

Over Land. Temperature inversions are produced mainly by night-cooling of the ground. Trapping may occur when the moisture distribution in the lowest layers is such as to reinforce, or at least not to counteract, the effect of the temperature distribution—that is, when the moisture decreases not too slowly with height. Night-cooling is greatest with clear skies and is quite small under an overcast. Hence, guided propagation over land occurs at night almost exclusively with clear skies. This type of temperature inversion is strictly confined to land areas. It does not occur over the ocean because the sea temperature does not show appreciable daily variations. Temperature inversions caused by night-cooling are most pronounced over dry land (desert) but will occur almost anywhere over land with a clear sky and a not too humid atmosphere.

Another phenomenon favorable to trapping is **subsidence.** By "subsidence" is meant the slow downward motion, combined with horizontal spreading, of air above the lowest layers of the atmosphere (Figure 3-81). This process, which most frequently occurs in the area of barometric high pressure, will produce temperature inversions; the subsiding air moreover becomes relatively much drier than the unaffected air below. In general, the subsidence inversion is quite high (e.g., above 4,500 to 5,000 feet). In the light of present knowledge, it appears that high subsidence inversions do not generally affect guided propagation when the sets are situated at low altitudes. It appears, however, that such subsidence inversions might materially affect communications on airborne radar search. Lower subsidence inversions (1,000 to 2,500 feet) along the southwestern coast of the United States are known to produce stable duct layers affecting radar coverage at low angles.

Turbulence of the air has a distinct normalizing effect in that it tends to smooth out the temperature and moisture variations which are conducive to guided propagation. Moderate to strong winds produce a turbulent layer extending normally to a height of about 4,000 feet. The air is well mixed within this layer and consequently the standard type of refraction prevails. Regions of a barometric low pressure are characterized by strong to moderate winds and pronounced turbulence in the lower layers. In addition, low pressure areas usually have overcast skies. Hence, a barometric low pressure will as a rule, lead to standard propagation.

It is extremely difficult to estimate in general terms the frequency of occurrence of guided propagation, since statistical data is almost nonexistent at present, except for very limited regions in Europe, such as the North Sea. In the Central Mediterranean during the summer months of 1943, ducts were observed on nine days out of ten. Frequent trapping has also been observed in some parts of the Pacific. At other times and places, guided propagation might be an unusual occurrence, especially if the barometric pressure is generally low and the winds strong. It seems advisable to consult a weather officer with regard to any given locality.

In order to determine weather's influence upon radar in a quantitative way, the variation of refractive index with height must be determined. This requires accurate knowledge of the temperature and moisture distribution in the lowest few hundred or thousand feet of the atmosphere. The ordinary radiosonde is not well adapted to measurements of this type because the measured points on an ascent are usually spaced several hundred feet apart. Among the methods which have been developed for this purpose during the past two years, the one most generally adopted uses a captive balloon (or kite) which carries aloft electrical temperature and moisture measuring elements. These are connected to a meter on the ground by means of thin wires attached to the cable holding the balloon. This device permits measurements at such closely spaced intervals as may be desired. A psychrometer held outside the window of a slow-flying plane has been used with some success in the absence of more elaborate equipment.

The following is a summary of basic facts concerning propagation at VHF, UHF, and SHF frequencies:

Standard propagation results in a slight downward bending of the rays throughout the atmosphere, leading to an increase of the horizon distance compared to the geometrical value. It is taken into account operationally by the use of covering diagrams with a 4/3 earth's radius; on a diagram modified in this way the rays appear as straight lines.

Guided propagation occurs almost exclusively in the lowest 2,000 feet above the

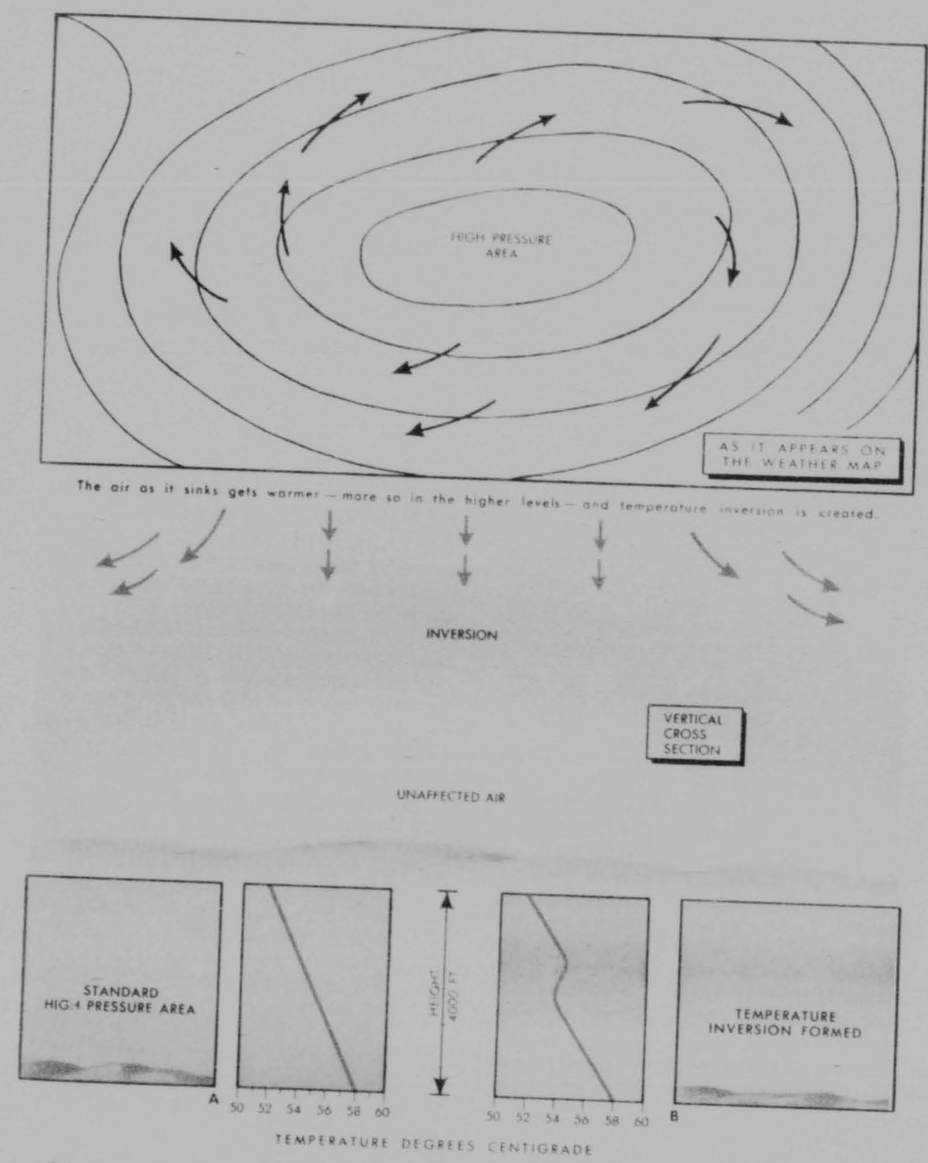

Figure 3-81 Subsidence (Sinking) in High Pressure Areas

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ground, and usually is confined to the lowest few hundred feet (except in warm climates).

Super-refraction resulting in guided propagation or trapping is produced:

a) By a pronounced decrease of moisture with height (moisture lapse), or

b) By a pronounced increase in temperature with height (temperature inversion), and

c) Particularly, by a combination of both of these two conditions.

Of the meterological conditions conducive to guided propagation or trapping, the most outstanding are:

a) Over sea—flow of warm, dry air over cooler water producing temperature inversions and evaporation into the lowest layers.

b) Over land—night-cooling of the ground with clear skies and calm air or light winds (if moisture distribution is favorable).

c) Over both sea and land—low level subsidence.

Conditions in a barometric high, including calm and clear skies and especially low level subsidence, favor trapping especially during the night (but do not necessarily produce it). Conditions in a barometric low, including strong winds, intense turbulence in the lowest layers, and overcast skies are conducive to standard propagation.

When the transmitter is within the duct, radar range is increased for surface targets (ships) and aircraft flying in the duct. At the same time there is an increase in fixed echo strength and consequently in ground clutter on the indicator. This may be accompanied by a change in the range of detection for craft flying above the duct.

When the transmitter is outside the duct, the range may either be increased or decreased from its standard value.

Effects of **nonstandard propagation** are negligible when the angle of elevation of the target is over 1°. Failure of detection at such angles must be attributed to other causes.

These echoes are caused by a reflection of the radar pulse from the rain drops in the clouds (or in rain storms). The amount of reflection increases rapidly as the frequency is increased. This occurs because the wavelength of the radio energy is approaching the same dimensions as those of the raindrop. Precipitation echoes are the exception at frequencies below 1,000 megacycles. In the application of microwaves to radar, these precipitation echoes at first appeared to be a nuisance. Recently, however, the precipitation echoes have been put to practical use in the field of weather observations. Storm detection radars are employed to chart the movement of storms and have proved successful in following the course of a storm.

Ground Wave Propagation

The ground wave is considered to be that portion of the radio wave which is affected by the presence of the ground and which would account for all the energy reaching the receiver if it were not for the ionospheric waves and tropospheric waves.

The ground wave can be divided conveniently into two components, a surface wave and a space wave.

Surface Wave

The surface wave is continuously in contact with the surface of the earth, and in cases where the distance of transmission makes the curvature of the earth a factor, extends its range by diffraction. The surface wave is practically independent of seasonal, dry, and night effects at frequencies above approximately 1,500 kilocycles.

The wave induces a current in the earth while traveling along its surface. If the earth were a perfect conductor, there would be no loss of energy, but the earth has appreciable resistance, and consequently causes an energy loss. This loss is made at the expense of the surface waves. Therefore, the range of the transmitted energy depends upon the characteristics of the earth over which it travels. Since sea water is a better conductor than the earth, a greater range will be attained. The losses, by attenuation, of the radio energy increase rapidly with increasing frequency so that at high frequencies the surface wave is unimportant, except for local communication. The surface wave range at frequencies in the vicinity of 2 mc is approximately 200 miles over average earth and perhaps two or three times greater over sea water for a transmitter radiating approximately 500 watts.

Space Wave

The space wave is the result of two component waves as illustrated in Figure 3-82, namely, a direct ray and a ground-reflected ray. When the transmitting and receiving antenna are both at the earth's surface, these two components of the space wave are equal in magnitude and opposite in phase thereby cancelling and leaving the surface wave as the only component of the ground wave. This is the case of **ground wave** transmission of broadcast frequencies, as the antenna heights are increased, however, the amplitude of the space wave rapidly increases, and soon becomes the principal part of the ground wave. This is the condition existing in the VHF and higher portion radio spectrum when the antennas are raised a few wavelengths above the earth.

The magnitude of the ground wave, and of its individual components, the space and surface waves, is influenced by the resistivity and dielectric constant of the earth, the frequency, the height of the transmitting and receiving antennas, the earth's curvature, the distance to the transmitter, and the variation of refractive index of the earth's atmosphere. The electrical constants of the earth affect the rate of attenuation of the surface wave, and also the reflection coefficient to which the ground-reflected wave is subjected. The height of the transmitting and receiving antennas affects the relative amplitudes and phases of the space and surface waves, and so influences the resulting field. The curvature of the earth makes it necessary for both the space and surface waves to diffract around the earth in order to reach a distant receiving point that is obscured by the curvature of the earth. The variation of density of the earth's atmosphere with height, (particularly the variation of moisture content), causes the refractive index of the atmosphere to decrease slowly with height above the earth. This causes the paths followed by the waves to be slightly curved, instead of straight as shown in Figure 3-82. This curvature is in the same direction as the curvature of the earth's surface, but is usually somewhat smaller in amount. However, if the earth's radius is assumed to be 4/3 its true value, then Figure 3-82 is correct since it takes into consideration the normal refraction.

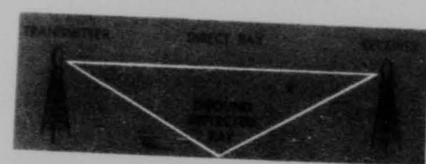

Figure 3-82 The Space Wave

The energy loss in ground absorption by a wave traveling close to the ground decreases rapidly with its height in terms of wave, therefore, can be relatively close (in wavelengths above the ground. A VHF direct physical height) to the ground without suffering the absorption effects which would occur at the same physical height with longer wave lengths.

Range Versus Height. Since the direct wave travels in practically a straight line, the maximum signal strength can be observed only when there is an unobstructed atmospheric path between the transmitting and receiving antennas. In other words, the antennas should be sufficiently elevated to provide such a path. On long paths, the curvature of the earth must be taken into consideration, as well as mountains or other obstructions.

Let us consider the height required to provide a clear line-of-sight over level terrain from an elevated transmitting point T (Figure 3-83) to a receiving point A on the earth's surface, neglecting for the moment the atmospheric refraction.

h = height of transmitter
d = distance between transmitter and receiver.
R = Radius of earth (4,000 miles)

The problem is to find h in the terms of the other quantities.

$$(R + h)^2 = R^2 + d^2$$
$$R^2 + 2Rh + h^2 = R^2 + d^2$$

The term h^2 is small compared to 2RH and, therefore, may be neglected without causing appreciable harm.

Then: $d^2 = 2Rh$ or $d = \sqrt{2Rh}$

In the practical application of this formu-

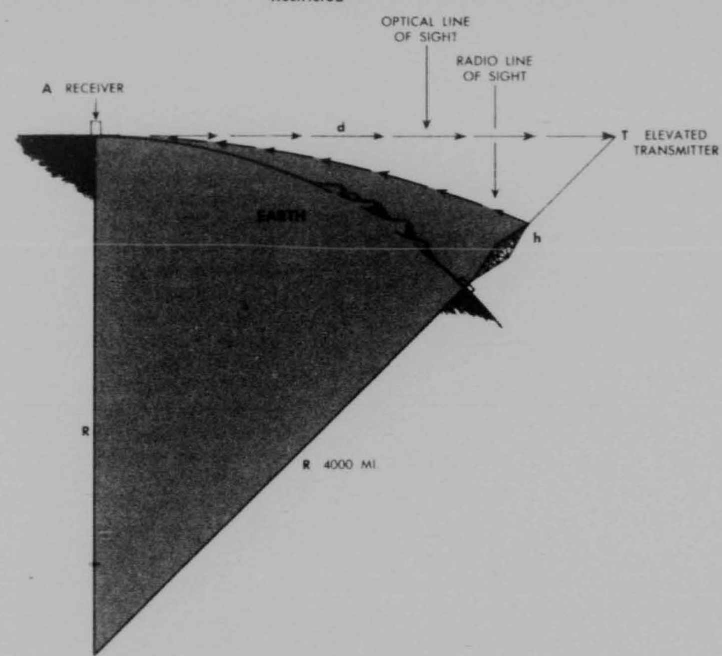

Figure 3-83 Curved Earth Geometry

la, it is desirable to express d in miles and h in feet. When this is done, the equation becomes:

$$d = \sqrt{1.51\,h}$$

However, when normal refraction is considered, the earth's radius then becomes 4/3 its true value and equation 22 then becomes:

$$d = \sqrt{2h}$$

When the transmitting and receiving antennas are both elevated, the maximum direct wave distance to ground level can be determined separately for each. Adding the two distances thus obtained will give the maximum distance over which direct wave communication may be had.

$$d = \sqrt{2h_1} + \sqrt{2h_2}$$

Where:

d = total distance in miles between transmitting and receiving antennas

h_1 = transmitting antenna height in feet

h_2 = receiving antenna height in feet

The subject of ground reflection and lobe formation has been discussed earlier in this section.

8. RECEPTION

General

The radio receiver has the function of converting radio waves into the original intelligence. Regardless of the type of modulation employed at the transmitter, the purpose of the receiver is to perform this conversion.

The receiver accomplishes this purpose by:

Collecting the transmitted signal.
Selecting the desired frequency.
Amplifying the radio frequency.
Detecting the signal.
Amplifying the detected signal.
Reproducing the signal from electrical current to sound waves.

Collecting the Signal

Just as the transmitting antenna acts as a radiating coil to generate magnetic waves, so does the receiving antenna act as a coil to intercept the magnetic waves. The magnetic waves produce a flow of current in the antenna which are brought into the receiver. For maximum efficiency, the receiving antenna should have the same polarization as the transmitting antenna, and the higher the frequency the more critical the size of the antenna.

Selecting the Signal

The first stage of the receiver is normally a series resonance circuit, that is, a coil and condenser in series with the antenna. The series resonance circuit is so designed that impedance is at a minimum only at one frequency. After the signal is established, succeeding circuits are parallel resonant circuits in which the impedance is highest at the desired frequency. This is necessary because each of the circuits feeds into high impedance vacuum tubes. The circuits must have an input which matches the impedance of the tubes.

Amplifying the Radio Frequency

All radio frequencies are of such low value when they reach the receiver that it is necessary to amplify them before it is possible to convert the signals to sound through detection and reproduction. Radio frequency amplifiers are normally class A.

Detecting the Signal

The purpose of the detector is to extract or recover from the modulated radio frequency the audio frequency which in turn can be converted to sound waves—the radio frequency signal does not carry an audio frequency component. The signal as transmitted through space is merely in the form of amplitude, pulse position, or frequency variations of the carrier wave, in no way is an audio component transmitted as such.

In the detection of radio signals superheterodyne, AM, or FM types are used.

A typical amplitude modulation type detector is the diode detector. (See Figure 3-84A). In this circuit, the cathode and plate are tied together and are connected at ground potential. No potential other than that of the impressed signal is on the plate. When the positive signals of the incoming cycle are applied to the grid, electrons will flow through L_1, R_1 and R_2 returning to the cathode.

An EMF across R_2 is built up through this process which charges C_2. Negative signals produce no current flow in the tube so the built-up charge leaks off through the resistors. This results in a series of voltage pulses (see Figure 3-84B) which produces a flow of current. The radio frequency component of these voltage pulses is removed by the filtering action of R_1C_3.

Diode detection provides high quality distortion-free signals with a sacrifice of amplification.

The output of the detector stage is amplified, normally, before it is fed into one of the receiving or converting devices which change current variations into sound impulses. With the exception of refinements of manufacture, radio receiving devices are similar to telephone receiving devices.

The typical amplitude modulation-type radio receiver consists of an RF amplifier,

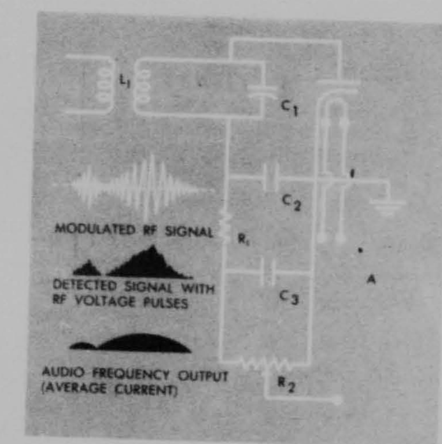

Figure 3-84 Diode Detection

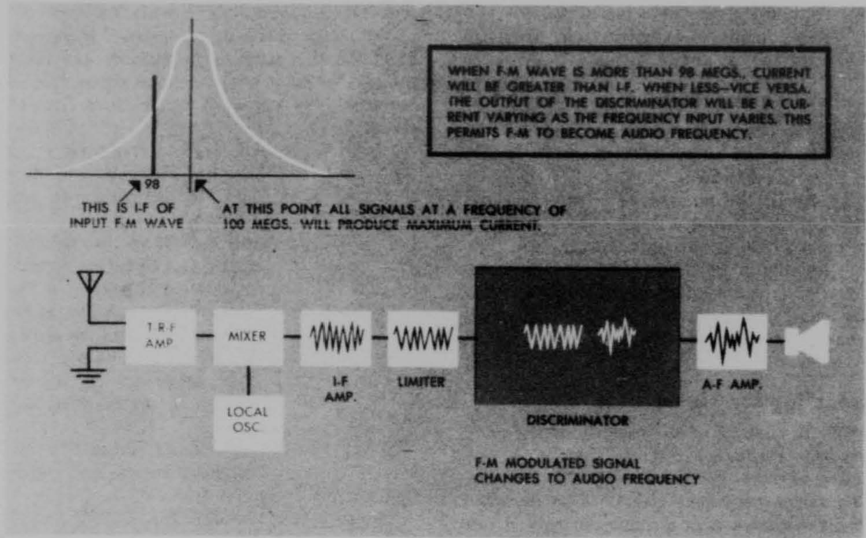

Figure 3-85 Discriminator Circuit

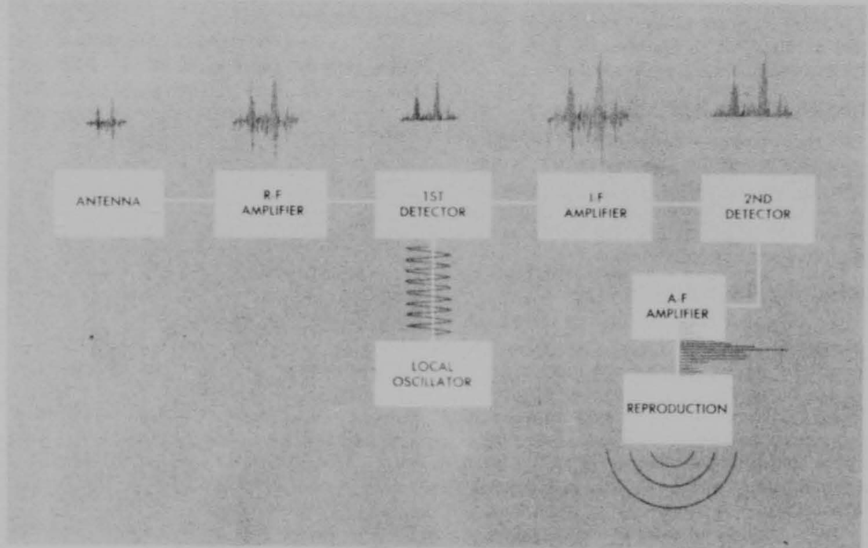

Figure 3-86 Block Diagram of Superheterodyne Receiver

local oscillator, mixer, IF amplifiers, detector, and AF amplifiers. This is shown in Figure 3-86. By adding the necessary components to this type of receiver, it is possible to convert it to a frequency or pulse-time modulation receiver.

The additional components necessary to demodulate frequency modulated signals are the **limiter** and the **discriminator.** A basic requirement of the FM receiver is that it be able to pass the required band of frequencies created by the transmitter. This band width might be as much as eighty kilocycles. A second requirement, and one which is necessary if the full noise-reducing possibilities of the FM system are desired, is a limiting device to remove all amplitude variations of the received signal, so that the signal varies only in frequency before it reaches the detector. A third requirement is that the detector or discriminator be capable of converting frequency variations into amplitude variations.

The **limiter** is a vacuum tube circuit so designed that the circuit will not pass currents above a certain amplitude. This is accomplished by means of tubes having a low plate potential. This low plate potential reduces electron flow regardless of the amplitude of the input signal.

The **discriminator** operates on the principle of applying the incoming frequency modulated signal to a circuit tuned to a slightly different frequency from that of the signal. A higher frequency will cause an increase in the current in the tuned circuit and a lower frequency will cause a decrease in current. (See Figure 3-85).

The additional components necessary to provide reception of audio frequency signals from pulse-time modulated transmitters are so complex in nature that a detailed discussion of the subject is not feasible in this text. The principles involved, however, are simple. Equipment used for this purpose should have the following characteristics: a sensitive receiver which uses the received pulses to activate the multiplex units, similar to those used in the transmitter; the multiplexes which take the pulse variations from the receiver and use them to trigger new pulses which are converted to sound. This conversion is accomplished by varying current flow in accordance with the pulse position.

The Superheterodyne. It is desirable in the receiver to have maximum sensitivity and selectivity. Because of the high bandwidth requirements of all radio systems, maximum sensitivity and selectivity can be obtained only by making a separate circuit for each frequency band. This is somewhat impractical, but it is the only way to achieve maximum efficiency in all stages.

The development of the superheterodyne circuit has substantially alleviated the difficulty. In this circuit, the incoming signal frequency is mixed with the local oscillator frequency. The resulting frequency called the **intermediate frequency** (IF) remains constant, regardless of the frequency of the incoming signal. Consequently, by engineering the following stages of the receiver to give maximum efficiency at this intermediate frequency, we are able to achieve great selectivity, great amplification, and better circuit stability.

The superheterodyne circuit accomplishes this by incorporating a well-shielded oscillator in the set. The output of this oscillator is varied directly with the frequency of the input signal. It is this direct variation that causes the resultant frequency to stay constant regardless of the incoming frequency.

This mixing normally occurs in what is called the **first detector.** The output is amplified and again detected. In effect, the intermediate frequency is a modulated current at a lower radio frequency. In some commercial sets, the local oscillator, detector, and amplifier are combined in one tube, called the "pentagrid converter." In Air Force equipment, the practice is to use a separate oscillator, the output of which is fed to a separate detector or mixer.

Audio Frequency Amplification. The output of the final detector will be a direct current at an audio frequency which by itself has no sound. Because most of the sound reproducing devices utilize varying currents of a fairly high value, it is necessary to amplify further the audio output. This amplification is normally class A or B in push-pull.

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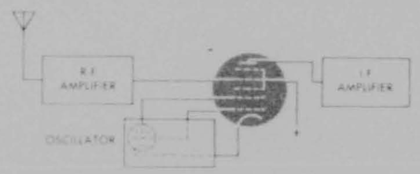

Figure 3-87 Pentagrid Converter

Sound Reproduction. The output of the audio frequency amplifier is ready for conversion into sound waves. Just as the microphone converts sound into electrical energy, so does the reproducer convert electrical energy into sound.

The headset of a radio receiver is identical with that of the telephone in operating principle. A permanent magnet is employed. About this magnet is a coil through which the audio-frequency amplifier output is sent. The variations of current will cause a diaphragm to vibrate and since the variations are at an audio rate the vibrations will be at an audio rate.

The headset does not permit much volume. For this reason a larger unit known as the "loudspeaker" is used. These are identical in principle with the headset differing only in size. The permanent magnet loudspeaker provides its own magnetic field; the dynamic speaker has a field coil which requires an external source of current to supply its magnetic field. The operation of these is identical.

Continuous-wave Reception. The receiver for continuous-wave transmissions must be constructed in the same manner as those receiving voice or tone-modulated signals. It must be realized that the CW transmissions are unmodulated, and, therefore, possess no audio characteristics. For this reason, the audio component must be added to the signal in the receiver itself. This is done with a device known as the **beat frequency oscillator** (BFO). This generates a radio frequency which, when mixed with the incoming signal frequency, produces a frequency that is at an audio rate. This permits an audio frequency to be fed to the final audio amplifier from which point it is fed to the reproducer.

Automatic Volume Control (AVC). Because the strength of radio signals will increase or decrease in transmission, it is necessary to provide a device which will insure a constant volume level. Without such a feature, the operator would be forced to sit at the set and continually operate the volume controls to adjust the output.

A typical simple automatic volume control is shown in Figure 3-88. In the diode detector, the more positive the plate the greater the current flow. Resistor **R** makes **X** negative in respect to **Y**. Therefore, the more positive the current flow on the plate, the more negative point **X** becomes. The grid in the radio frequency amplifier receives its bias from this point **X**. Thus, the greater the signal impressed on the plate of the detector, the more negative the bias on the radio frequency amplifier which in turn reduces the original amplification. Likewise, weak signals allow the grid to become less negative, permitting greater amplification. In this manner, an automatic control of volume is attained.

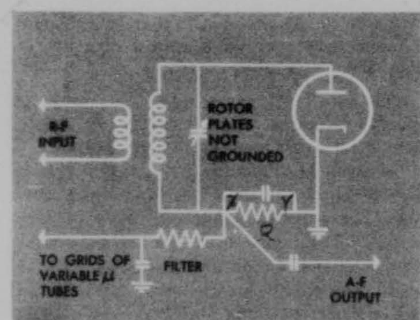

Figure 3-88 Automatic Volume Control

SECTION 3 - MILITARY APPLICATION OF RADIO

1. GENERAL

In conforming to the **six principles of communications**, namely, **reliability**, **security**, **speed**, **economy**, **flexibility**, and **system integration** it is apparent that radio, in its various applications, affords a suitable answer to four of these principles, speed, economy, flexibility and system integration.

In discussing the agencies of radio communication, it is appropriate to consider the reasons for selecting various bands of the spectrum for specific purposes, and their application to Air Force functions.

2. EMPLOYMENT OF THE RADIO FREQUENCY SPECTRUM

The radio frequency spectrum extends, for all practical radiation purposes, from **30 kcs** to **30,000 mcs**. As equipment ranging from huge transoceanic transmitters to miniature pack-carried sets utilize this spectrum, a discussion of the characteristics of each of the frequency bands is essential to an understanding of the various types of radio.

Low Frequency

Low frequencies are used in a few instances by the Air Force, principally for the radio range. Inasmuch as the radio range is a widely used piece of equipment, a discussion of low-frequency equipment is appropriate.

The low frequencies extend from 30 to 300 kcs. It is general practice, however, to extend the low-frequency band to include the wave lengths from 10,000 meters to 600 meters.

Low-frequency radio equipment has certain characteristics which are of sufficient importance to be considered. They are briefly:

a) Ground wave propagation is the best transmission method for low frequencies. Therefore vertical antennas are used.

b) Low frequencies travel great distances over water when vertically polarized. This is because of the high conductivity of water.

c) The easy absorption of low frequencies requires high powered transmission to attain the desired coverage.

d) Because of the long wavelengths used and high power required, low-frequency sets are very heavy and in most cases are used only when permanent installation is feasible.

e) Low frequencies are easily affected by static, limiting their use as a voice communications means.

f) Skywave propagation is of no importance since the ionosphere absorbs low-frequency signals. Global reception of low frequencies cannot be expected at all.

Except for specialized use in the Arctic regions, low-frequency transmissions are of limited value under most conditions.

Typical Low-frequency Equipment. Although low-frequency equipment was used in the early days of radio for communication purposes, the development of higher frequency techniques has resulted in its restricted use. The principle use of low frequency in the Air Force is in the **range stations.** A typical low frequency range transmitter has these characteristics: amplitude modulated, 50-300 watts output, very high vertical antennas, large AC or DC power supplies, and a range of from 30 to 100 miles, increasing greatly over water.

Radio ranges use low frequencies for these reasons:

a) Ground waves are more dependable and provide a steady wave in all directions.

b) Absorption of sky waves prevents reception of spurious signals by the pilot.

c) When transmitted over water, low frequency gives excellent coverage for very long distances.

(The theory of ranges will be discussed later in this section.)

Medium Frequencies

Medium frequencies (300 kc-3000 kc) provide a band of highly useful frequencies which are used extensively in commercial broadcast work. They have good ground wave range extending to about 100 miles and a nighttime sky wave range in excess of 1000 miles or more.

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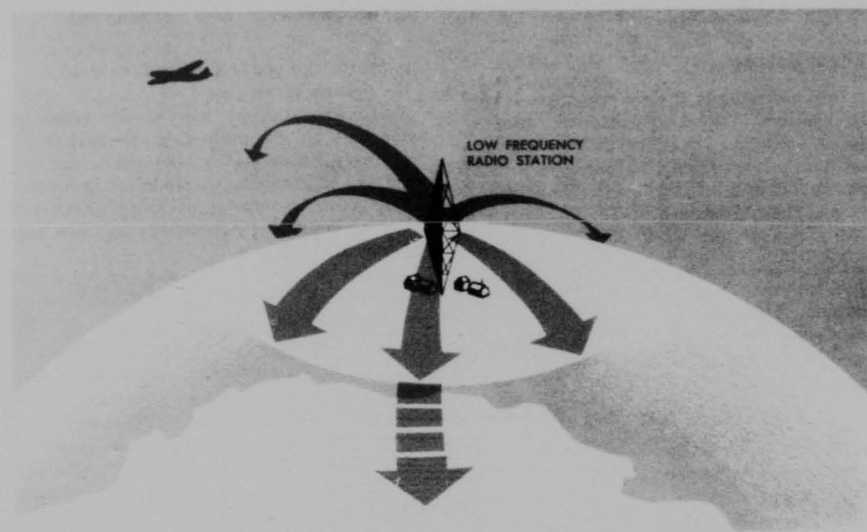


High Frequencies

High frequencies are in the band from 3000 kcs to 30,000 kcs. Although the present trend of radio communications is toward greater use of the spectrum beyond 30,000 kcs, certain characteristics of high frequencies make the band best adapted for long range radio communications.

Between the low and high frequencies are the medium frequencies in which are included the commercial broadcast stations. For purposes of discussion, these may be considered as being in the high-frequency band.

Disadvantages of High Frequencies. Principal disadvantages of high frequencies are as follows:

a) Ionospheric changes cause fading, sporadic absorption, and seasonal variation in signal reception.

b) Antenna requirements restrict vehicular use. Although high frequency is used for mobile radio equipment, much of the power is lost in loading the antennas which usually are shorter than the required lengths. A compensation device is required to take up this difference in length with a consequent loss of power.

c) Crowded conditions in the high-frequency spectrum require peak frequency stability in high-frequency equipment.

d) Ground wave propagation is of little value in the tropics because of extremely high signal absorption; thus, close range communications must be accomplished by means of sky wave transmission.

e) Power requirements are high and equipment is heavy.

f) High-frequency signals are subjected to distortion caused by static. Storms of an electrical or auroral nature often cause a black-out in communications.

Advantages of High-Frequency Communications. Despite these disadvantages, the backbone of most point-to-point radio communications is high frequency. No other band affords these advantages:

a) Good range under most normal conditions.

b) Extremely long range under favorable conditions.

c) Manner of polarization is not critical unless extreme distance sky wave transmission is desired.

Very-High-Frequency

It can be said without exaggeration that the development of equipment using frequencies from 30-300 megacycles has led to the advancement of much of the tactical employment of radio. It is this band of frequencies, as we shall see later, that has made radar a practicality.

The list of points favoring very high-frequencies over high frequencies is extensive, and many new uses for very-high-frequency equipment will undoubtedly be developed within the next few years. Already we find the high-frequency command radio supplanted by a very-high-frequency unit and within a period of years the low-frequency radio ranges will be replaced by very-high-frequency units.

Advantages of very-high-frequency are as follows:

a) Small power requirements facilitate the use of lighter sets and thus contribute to greater mobility.

b) Line-of-sight operation permits the same frequency to be used in many areas with a minimum of interference.

c) VHF offers better security than does high frequency, because of the line-of-sight factor.

d) It is less susceptible to atmospheric interference then the lower frequencies.

e) It is unaffected by normal ionospheric changes.

f) Because the antennas used are small, it is possible to achieve high gain in a particular direction with a small reflecting device; a similar device is impractical for high frequencies.

g) Because the antennas are small, it is possible to get good results whether the set is mobile or stationary.

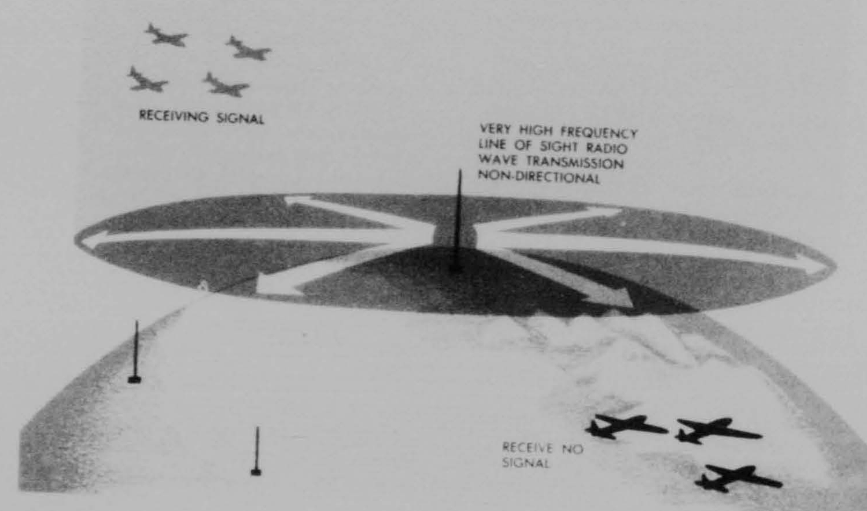
Above Very-High-Frequency

Above 300 mcs are found the range of frequencies used extensively in radar and in pulse-time modulation equipment. At these frequencies conditions are similar to those of very-high-frequency except that power requirements decrease, antenna gains are better, and the susceptibility to static drops. In this band, line-of-sight decreases effective transmission distance.

3. GROUND RADIO COMMUNICATION

General

The employment of radio under field conditions is a problem that is often faced by



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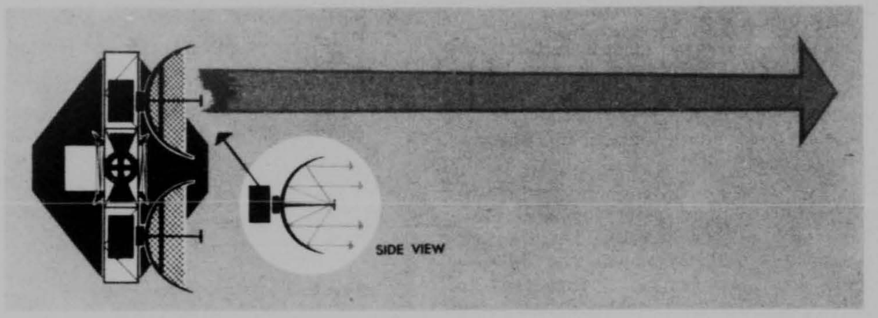


the communications officer and requires considerable planning in order to achieve the desired results. In order that a proper site be selected, it is necessary to consider several factors which will affect the end result. These factors include: technical requirements, cover and concealment, and local communications.

A radio station should be located in a position which assures communication with all other stations in the radio net. In order to obtain the most efficient operation for transmission and reception, certain features of the existing situation must be considered.

One of the most important features is that of the terrain surrounding the station. Hills and mountains rising between two stations will reduce the range of communications when ground wave or line-of-sight propagation is employed. When operating in hilly or mountainous terrain, sites should be selected relatively high upon the slopes. Locations at the base of a cliff or in a deep ravine or valley.

Dry ground has low conductivity and therefore reduces the range of transmission. It is desirable that a site be chosen near moist ground, since the value of conductivity is greater resulting in an increase of range. Water, particularly salt water, greatly increases the range expectancy.

Trees are to be avoided since the foliage absorbs radio energy and greatly reduces the range of transmission. Deciduous trees have a more adverse effect upon radio transmission than do evergreens. The antenna should be clear of all foliage and dense brush in order to attain the greatest possible efficiency.

Man-made obstructions are another source of interference with radio communications. It is inadvisable to select a position in a tunnel, beneath an underpass, or a steel bridge. Under these conditions, reception will be impossible since a large amount of the energy will be absorbed by the steel structure. Buildings between radio stations will hinder transmission and reception in much the same way as will hills and mountains. Steel and reinforced concrete buildings are worse offenders in this respect than wooden buildings.

All types of pole wire lines, such as telephone, telegraph, and particularly high voltage power lines, should be avoided in selecting a radio site. Such wire lines absorb power from the radiating antennas located nearby. They also introduce hum and noise into the receiving antenna.

Locations adjacent to heavily traveled highways are to be avoided. In addition to the noise and confusion caused by the traffic, ignition systems in the motor vehicles may cause local interference with the radio receiver and make reception under certain circumstances impossible. Battery charging units and other electrical generators should not be located too close to a radio station since they are potential sources of radio interference.

Care must be taken to see that radio stations are not located too close together since this is a potential source of interference between adjacent stations. Radio stations radiate harmonic frequencies as well as the fundamental frequency. A near by station may be able to detect and amplify these harmonics which cause interference within its assigned receiving frequency. Great care must be exercised with the placement and selection of operating frequencies assigned to frequency-modulated radios because of the interference explained above.

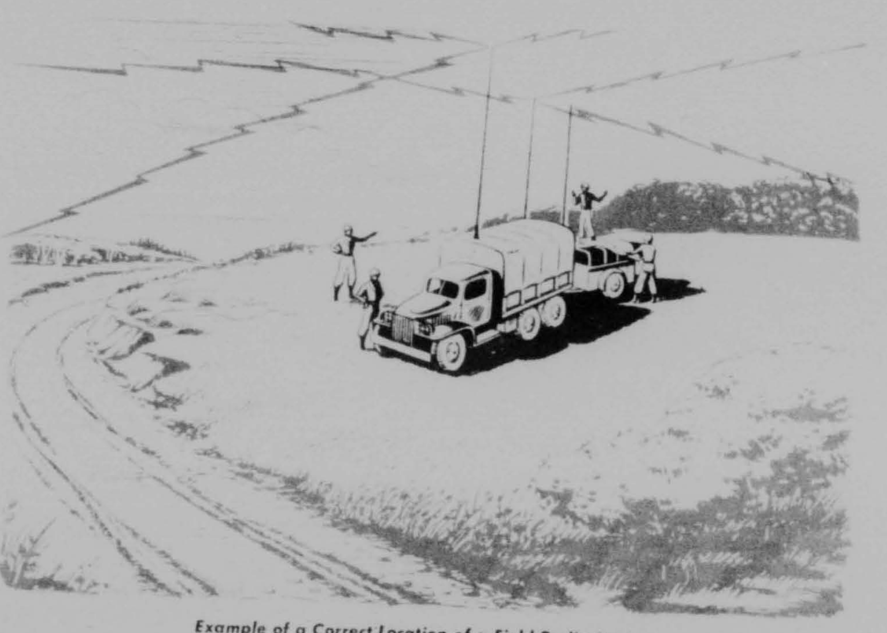
In addition, it is necessary to consider the local command requirements in the selection of radio station sites since they must always serve that headquarters adequately. The stations should be close enough to provide the required service but not so close to attract undue attention to the location of the friendly headquarters. (The minimum allowable distance between headquarters and the radio station is 200 yards.)

Sites should be selected so that the maximum cover and concealment consistent with good transmission and reception is available. The open crests of hills and mountains, although providing good transmission characteristics, should be avoided since the equipment is then silhouetted against the sky and makes an excellent target for enemy fire. A slightly defiladed position just behind the crest of the hill will provide better concealment without sacrificing too great an amount of radio transmission range.

In many cases, it is possible to install the transmitters and receivers in underground shelters, thereby enabling the communications to be carried on under severe battle conditions. The antenna is the only portion of the radio that must remain in the open.

Radio Call Signs

Radio call signs are employed to identify individual radio stations. A call sign consists of characters used to afford a short and secure means of conveying the identity



Example of a Correct Location of a Field Radio Station

Example of an Incorrect Location of a Field Radio Station

of stations, commands, and commanders. These call signs are the only identification employed between radio stations. The call sign may consist of a three-letter or a combination letter and number group when International Morse code is used. Call signs between voice radio stations normally consist of one or two words. Call signs are changed frequently in order to afford the desired degree of security. The proper call signs and their use are prescribed in the Communication Operation Instructions (COI) for each unit.

Interference and Jamming

There are few receiving locations entirely free from either natural or man-made static and such interference may be extremely troublesome at times. Under these conditions of static, the following steps should be taken to minimize and improve the reception.

a) If the receiver is equipped with a crystal filter, much of the extraneous noise frequencies on either side of the desired frequency may be eliminated. The crystal filter is a highly selective device and may be tuned so that much of the undesirable noises may be removed from the incoming signal. This device always should be employed first since it is the most effective one at the disposal of the operator.

b) The receiving antenna should be checked to determine that it is free from all obstructions and contact with trees and shrubs which will cause objectionable noises in the receiver.

c) If the antenna is provided with an external connection, the length of the antenna should be varied. Increasing or decreasing the length of the antenna may result in better reception of the desired frequency. This operation is largely an experimental one and it may take considerable time before the correct length is discovered.

d) The volume control on the receiver should be adjusted to the lowest level at which the desired signal can be heard.

e) Headphones should be employed in preference to a loudspeaker since it is possible to detect a weaker signal with a headphone than with a loudspeaker.

Jamming is the transmission of radio signals with the intent of blocking out or interfering with radio communication for the purpose of causing disorganization among opposing troops. Deliberate jamming of radio communication by the enemy must be expected.

Jamming is more or less effective, depending upon the power of the jamming transmitter and the type of interference being radiated. Jamming signals may consist of keyed continuous waves, tone, voice, music, imitation static, or other types of noise signals. The jamming signals may be undamped, amplitude-modulated, frequency-modulated, or a combination of these. Frequency shifts, made by the operator, may be employed to alleviate this condition. A number of jamming transmitters may be used simultaneously in order to cover some radio frequency band.

The effectiveness of radio jamming may be reduced if it is anticipated and planned for accordingly. The COI should include additional, widely separated, frequencies with instructions on their use in case of radio jamming. Changing frequency will often give sufficient time to complete the message or messages before the enemy can find the new frequency and change his jamming transmitter. Enemy jamming on one frequency may be discontinued if it is thought that the channel is no longer in use; therefore, it is good policy to maintain dummy transmissions on this channel in the hope that the enemy will continue to jam this channel rather than put his equipment to work on another channel.

The best defense against jamming is the proper training of radio operators to cope with the interference. Operators must be trained to operate through heavy interference of all types. It has been found that in general, tone modulation is more readable through jamming than CW or voice modulation. In general, the operator may reduce the effectiveness of jamming by performing the following operations:

a) Use the crystal filter of the receiver to tune out as much as possible of the undesired signal.

b) Authenticate all incoming messages since the enemy may intersperse jamming with false messages.

c) Change call signs and frequencies as directed in the COI.

d) Eliminate preliminary calling, requests for reports on signal strength, and other routine messages which are not necessary for conduct of the traffic.

Above all else guard against the possibility of panic at the first signs of jamming since this is the result desired by the enemy. Expect jamming and have the determination to get the message through under any conditions.

Transportation of Ground Radio Equipment

Radio equipment is comparatively delicate and its serviceability is governed to a great extent by the care with which it is packed for transportation. Operating equipment will be packed and loaded to protect it from dust and dirt, weather, shocks of the road, and from injury from other articles loaded in the same vehicle.

Representative Types of Ground Radio Equipment

Figures 3-89 through 3-92 are illustrations of typical ground radio equipment employed in the United States Air Force. A brief technical description of each set shown, and of others, is included in Appendix IV. These do not represent all the equipment of this nature employed in a military operation as space does not permit a more detailed discussion of all the sets that may be encountered in the field.

4. AIRBORNE RADIO COMMUNICATION

General

The principles involved in airborne radio communications are the same as those employed in ground radio. The important difference is one of design. The radio for airborne communications is handicapped by several features that are not imposed upon

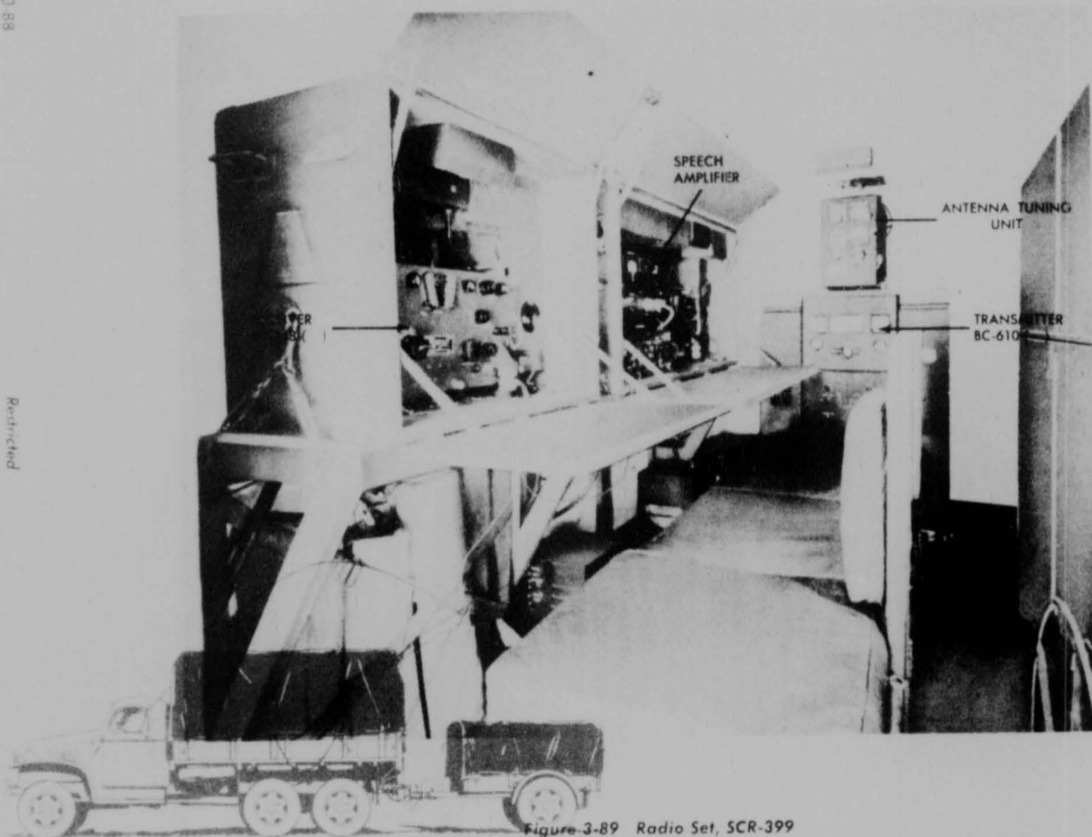


Figure 3-89 Radio Set, SCR-399

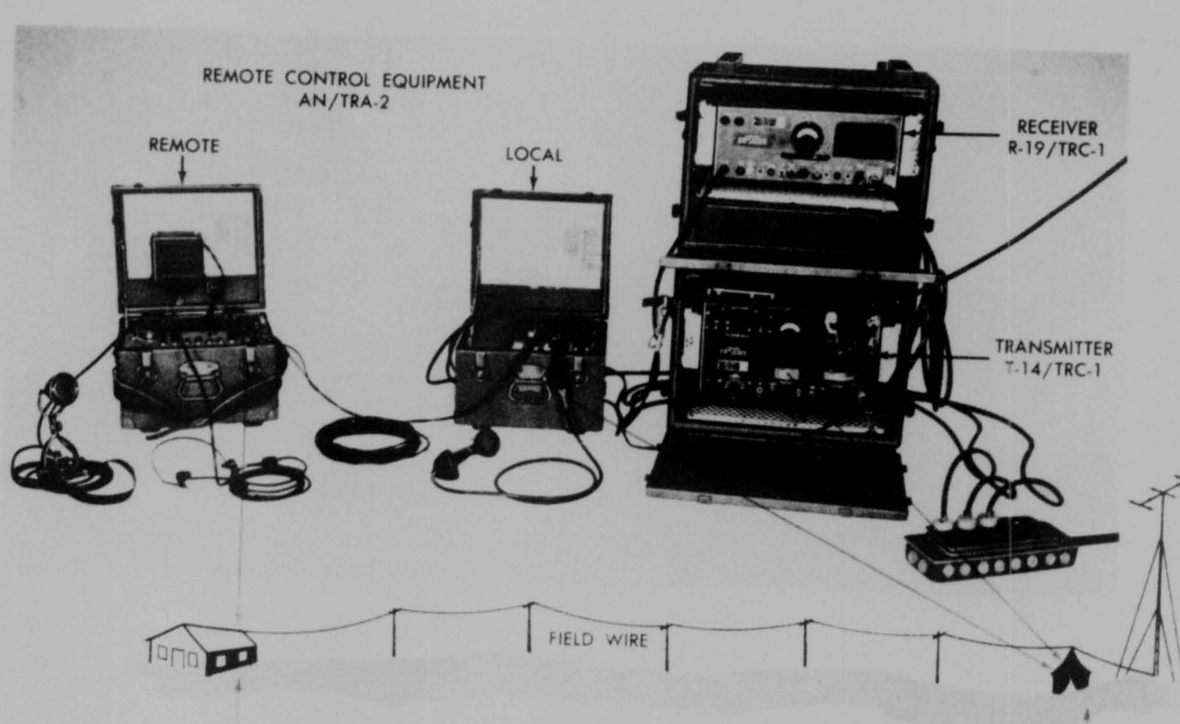


Figure 3-90 Radio Set, AN TRC-1

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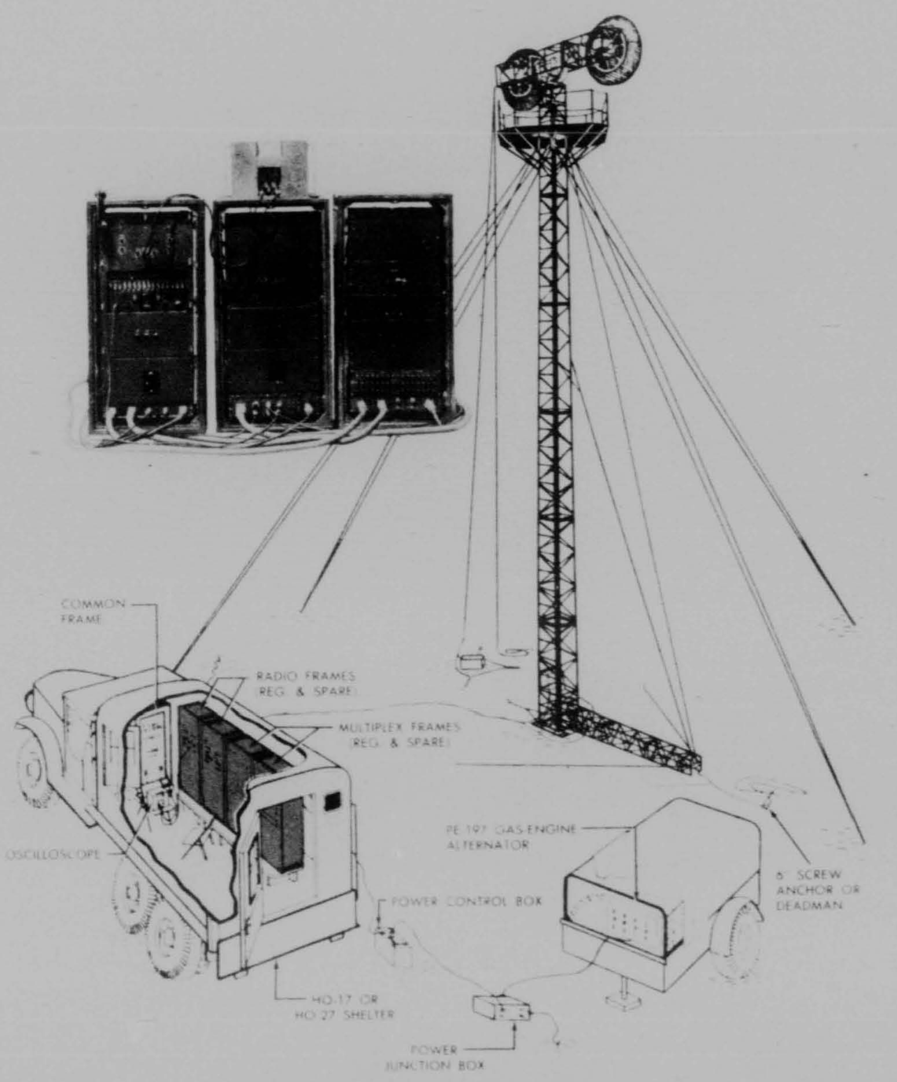


Figure 3-91 Radio Set, AN TRC-6

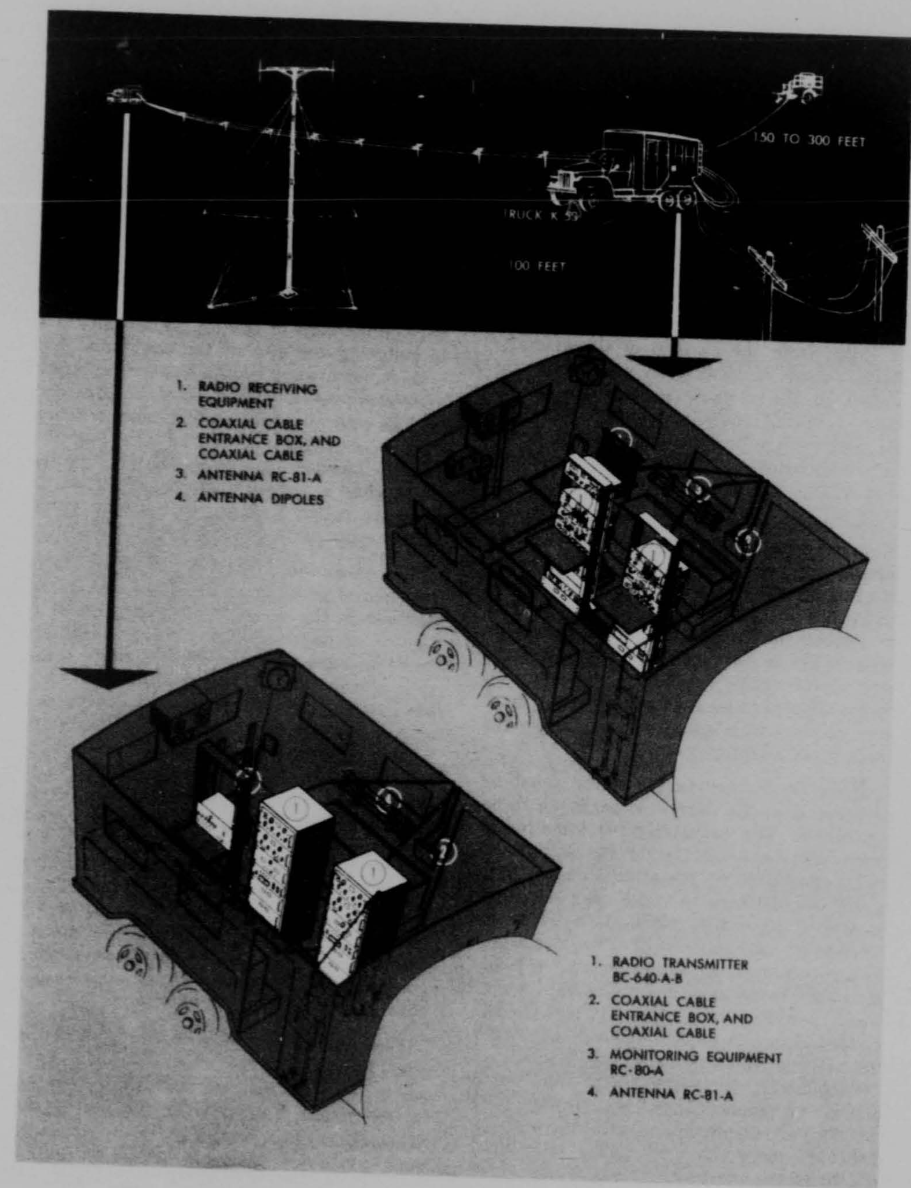


Figure 3-92 Radio Sets, SCR 573-574

ground radio equipment. The factors of weight, space, altitude, and antenna design must be considered in the construction and employment of airborne radio equipment. At first glance, these items may not appear to be serious, but after some consideration, it is apparent that they will impose great limitations upon performance. These factors do not play such an important part in the design and construction of ground equipment.

Weight is an important item when it is considered that for each pound of equipment installed in the aircraft, a pound must be taken from the payload of the aircraft. Each pound of additional equipment installed in the aircraft reduces the maximum potential fuel and bomb load. Each piece of such added equipment must prove its worth before it is considered for inclusion in the aircraft.

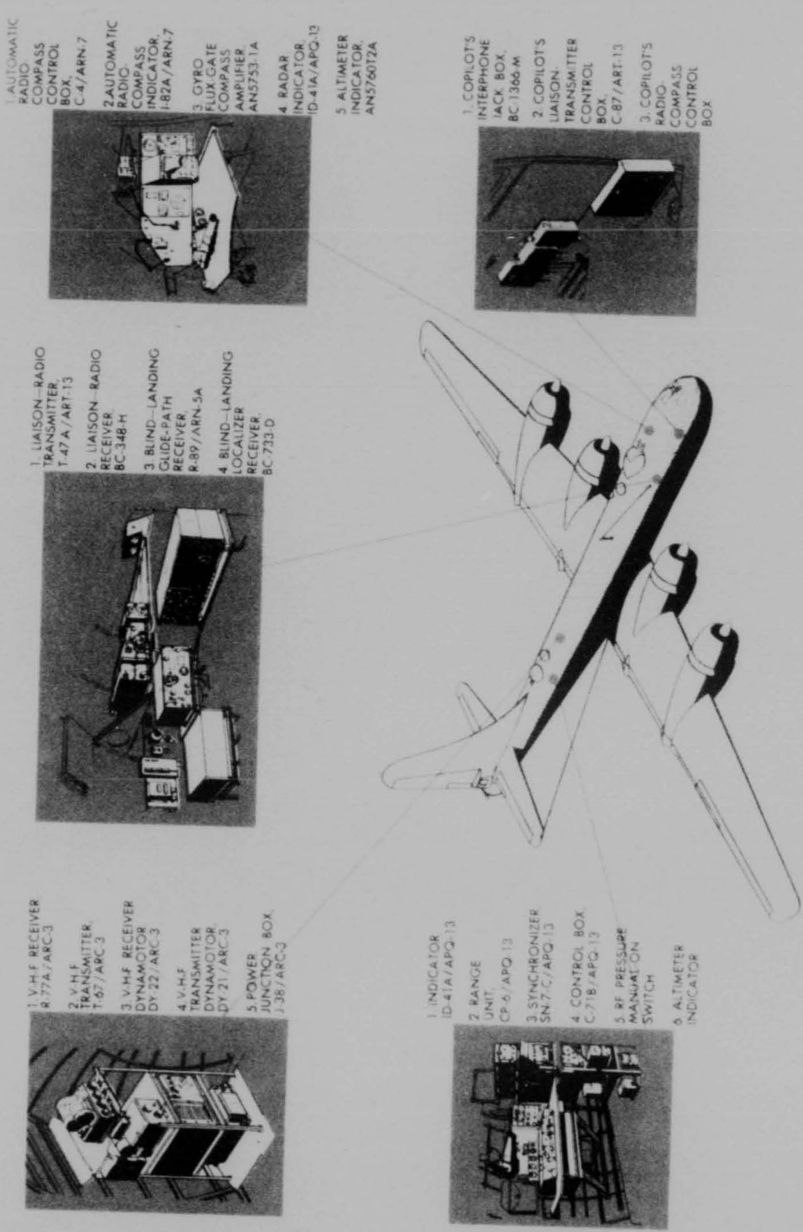
The designer is faced with the problem of minimizing the weight factor of the equipment, yet producing an item capable of standing the rough usage to which it will be subjected in flight. One method employed to reduce the weight in electronic equipment is to use primary voltages of frequencies of 400 cycles instead of the usual 60 cycles. This permits the use of transformers and reactors of a smaller size and weight for a given output.

Space is another factor which must be considered in the design of airborne radio equipment. The designer must know what space will be available for his equipment and design it to fit the alloted space. Normally, he will have to make the equipment in several parts and place these wherever there is a small amount of space available. This requirement is not so rigorous for bombardment types as it is for the fighter aircraft; nevertheless, it must not be neglected. Space is not always available near the position which the operator will occupy. Consequently, it is necessary that some method of remote control be provided. The problem of remote control is not extremely difficult except that it imposes additional weight to the equipment, and may accentuate maintenance problems as it creates more places for trouble to occur.

One problem in connection with design of airborne electronic equipment is that of high-voltage arcs when the equipment is being operated at high altitudes. The dielectric constant of air at high altitudes is less than it is at sea level. One method of solving this problem is to increase the size of the insulators and the amount of spacing between the parts of the equipment. This expedient should be avoided if possible, however, as it increases the space and weight requirements of the equipment. Another method often employed with radar equipment is that of pressurizing the high voltage portions of the set. This is effective in reducing the size of the equipment but it does not always reduce the weight, since a pressure-resisting case must be provided for the equipment. The third method which may be employed is that of reducing the voltage applied to communications equipment after a certain altitude is reached. A pressure switch is employed to activate this change-over at the predetermined altitude.

The design of antennas is becoming a problem of great importance with the rapid increase in the speed of aircraft. The addition of antennas on the surface of the aircraft increases drag proportional to the cube of the velocity. Therefore, it is desirable that the antenna system be so designed as to reduce the drag factor to an absolute minimum. Undoubtedly the antenna of the future will be fully contained in the fuselage of the aircraft—imposing new problems in design. The airborne antenna must be so designed that the fuselage will not shield it from the desired radiations. This may involve more than one antenna for a communication receiver and consequently increase the complexity of the system. At the present time, this problem is receiving considerable attention but a satisfactory solution has not been found.

Finally, mention should be made of the need for multichannel airborne radio equipment. If all aircraft transmitters were to be of the single channel type; that is, if the transmitter has to be retuned manually each time a new frequency is used, flexibility of communication would be lost. Older types of airborne equipment were of the single



Airborne Radio Communications Equipment

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channel variety. In aircraft which carried a radio operator, this was not a serious problem although retuning was time-consuming. In fighter aircraft, the alternative was to employ more than one transmitter in order to provide more than one channel.

Modern developments have brought about multichannel equipment. A high-frequency transmitter with ten pretuned channels is currently in use. The radio operator may change frequency merely by turning a selector switch. Very-high-frequency transmitters with eight pretuned channels are in use and newer equipment is being developed capable of providing many times more than this. To select a channel, the operator pushes a channel selector button. In a later phase of the study of United States Air Force communications, the need for this type of radio equipment will be discussed.

It may be seen readily that the factors involved in the design and construction of airborne electronic equipment are conflicting, and, at best, only a compromise solution to make the best possible compromise solution.

Essentially, the operation and employment of airborne radio communications is the same as for ground radio communications. The same regulations concerning call signs and security apply.

Representative Types of Airborne Radio Equipment

Figures 3-93 and 3-94 are illustrations of typical airborne radio equipment employed in the United States Air Force. A brief description of this equipment is included in Appendix V.

5. RADIO AIDS TO NAVIGATION

General

Many developments have occurred, to make flying easier and safer. Navigation under instrument conditions is greatly simplified by reference to the radio and radar aids which are available.

A comprehensive system of radio aids to navigation has been installed in the United States and on all the important airways throughout the world. These provide navigational facilities which are available for use under contact or instrument flight conditions. In all types of air operations, one of the prime factors in determining the success or failure of a mission is navigation. Bad weather conditions have been responsible for the loss of many aircraft. The losses have been caused largely by the lack of adequate radio aids to navigation or the inability of the pilot to use those provided. The inability to navigate and identify targets under all conditions of visibility has resulted in aborted missions, disaster to airborne operations, and the bombing of friendly troops.

All radio aids to navigation operated by agencies of the United States are listed in the Radio Facility Chart AN 08-15-1. Copies of these charts are carried in all aircraft and are revised frequently. Notice of changes which occur between revisions of the chart are brought to the attention of all concerned through radio or teletypewriter messages called Notices to Airmen (NOTAMS). A file of NOTAMS is maintained at every civilian and military air terminal.

Radio Ranges

Radio ranges are located adjacent to important airfields and are spaced at intervals along important airways, comprising an important aid to a pilot in navigating from one point to the next. Ranges located near an airfield perform another important function. One of these legs, or courses, is usually directed over the best runway of the field. In bad weather, the pilots approach the airport on the radio range and make a **procedure let-down** on the course that will bring them to the proper runway. This procedure has been standard practice for many years with the Civil Aeronautics Administration. Aircraft may be stacked on the various legs to await their turn in the event of bad weather. With the modern developments in landing systems the radio range procedure let-down is being used less frequently.

The radio range transmitter emits an aural signal by means of which the pilot may determine his direction in respect to the station to which he is listening and determine his position with respect to established airways. Generally, all range equipment transmits so that two or four beams or courses are ob-

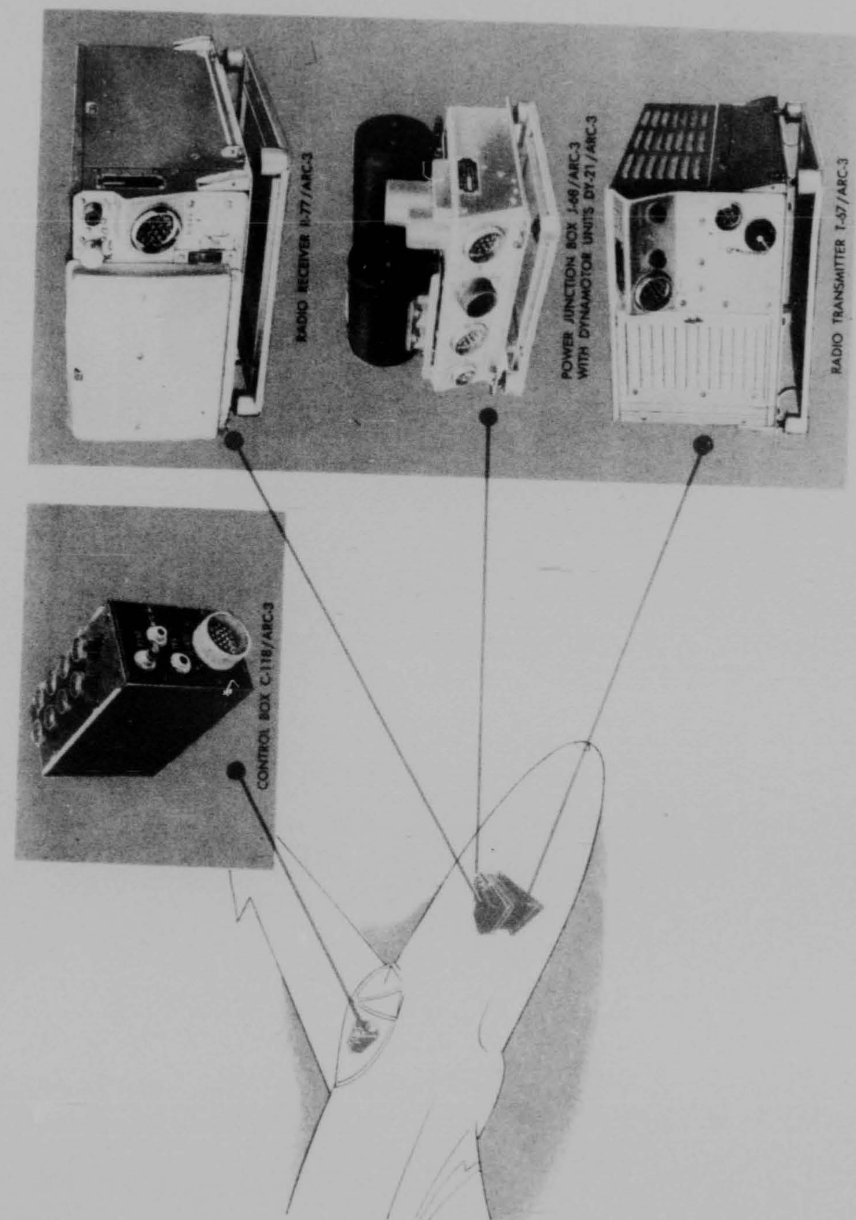


Figure 3-93 Radio Set, AN ARC-3

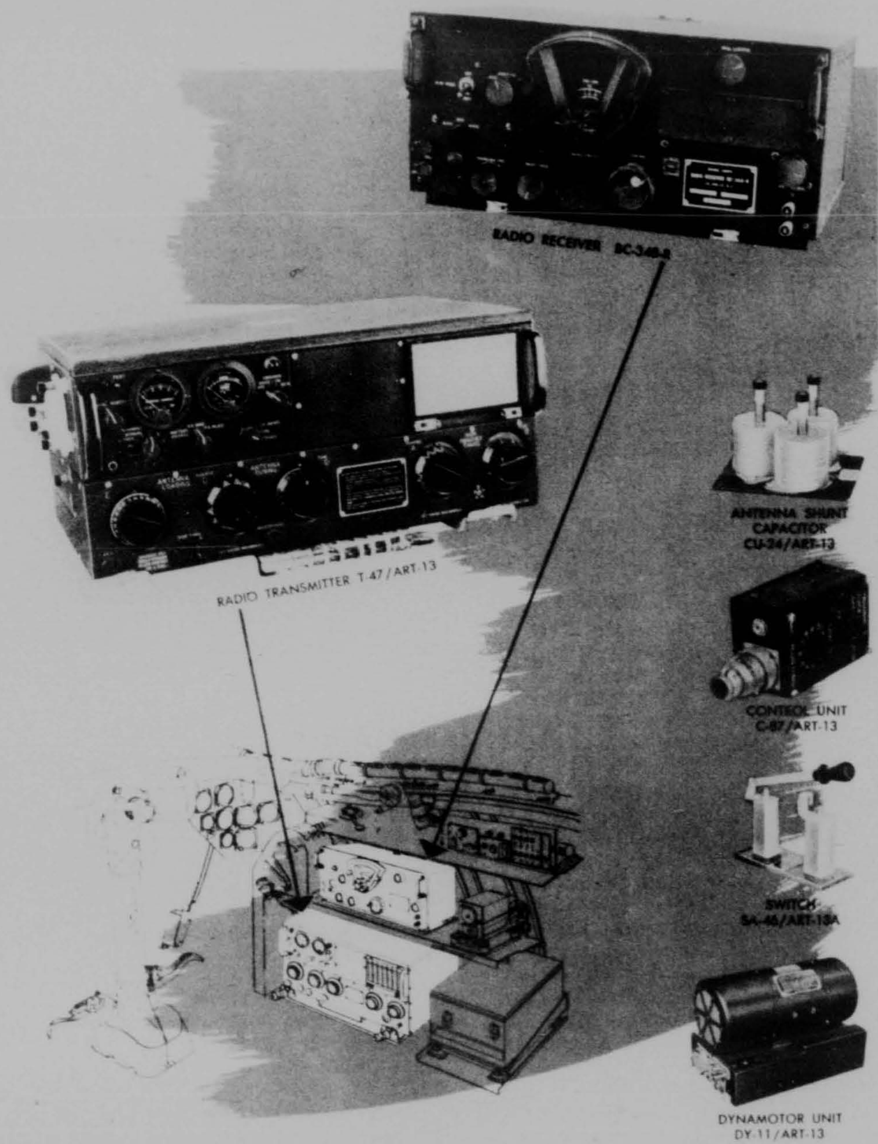
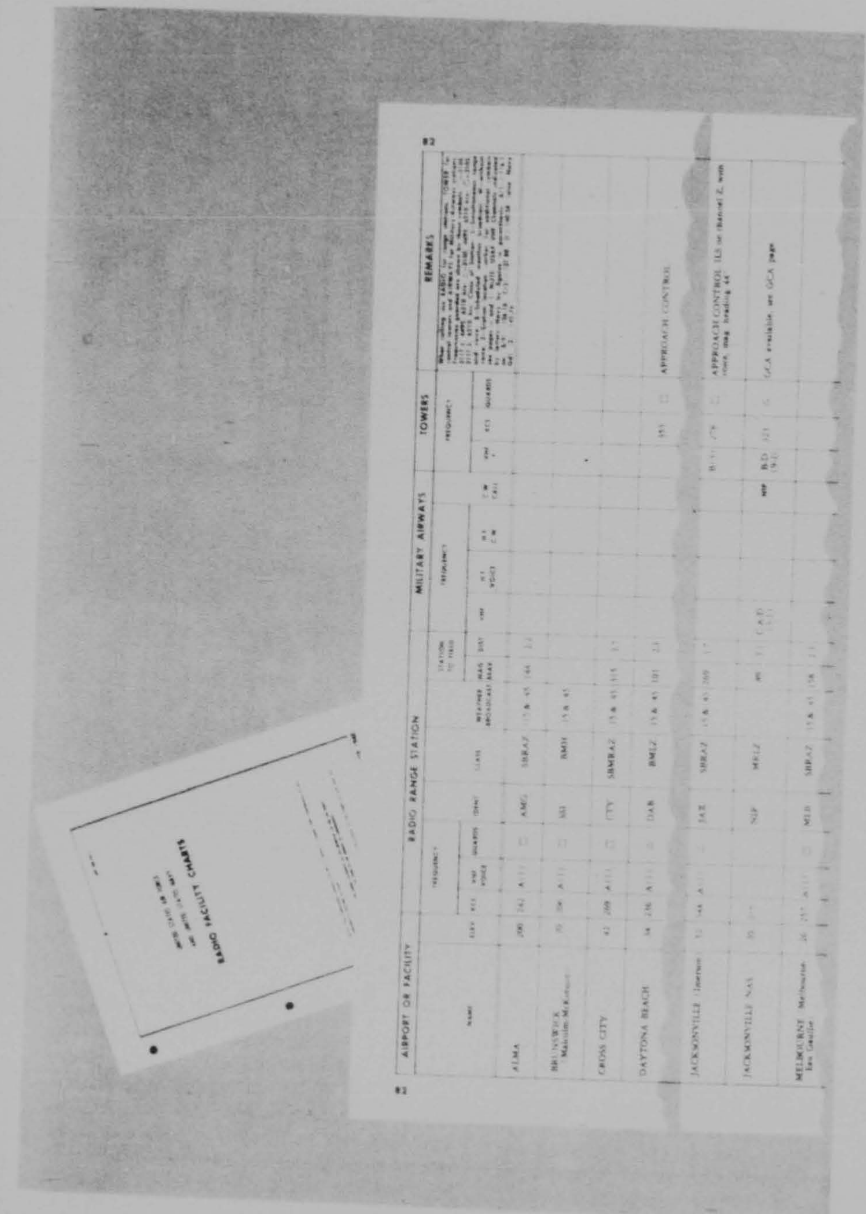


Figure 3-94 Radio Set, AN ARC-8



Radio Facilities Chart

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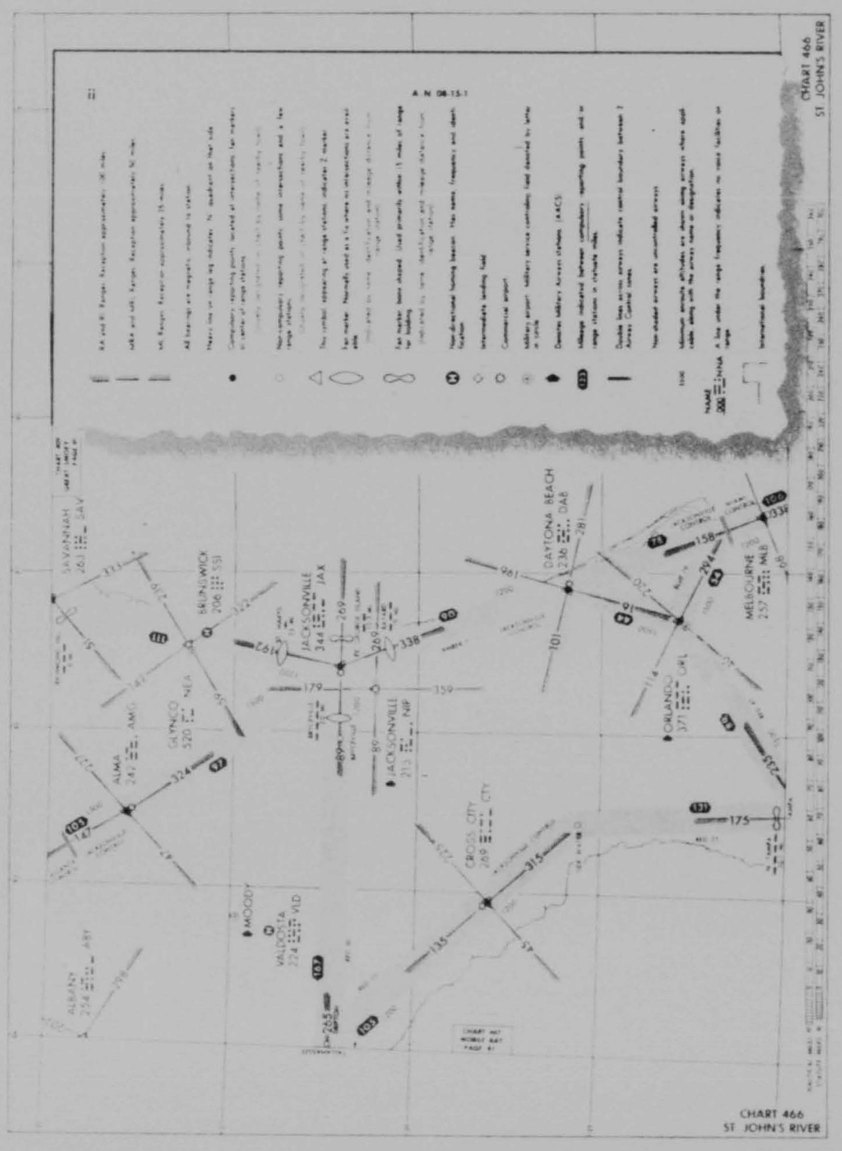


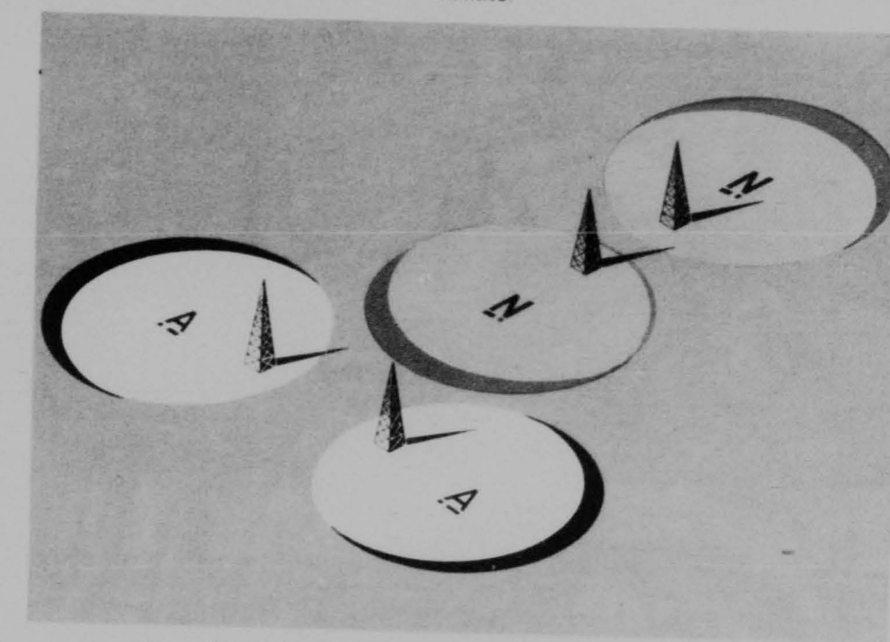


Figure 3-95 Directional Antenna Pattern in Unrelated Pairs

tained. The courses are normally placed parallel to established airways. A pilot can use the radio range as an aid to navigation, if his aircraft is equipped with a receiver capable of receiving the frequencies employed for transmission. No special equipment, such as a loop antenna, radio compass, or indicating equipment is required to fly the course of a radio range. All transmissions are modulated so that the receiver does not need a beat oscillator.

The following is the theory of operation of one particular type of four-course radio range. The field pattern of a single vertical antenna is theoretically circular. Two vertical antennas driven by a single transmitter will produce a field pattern similar to a figure eight. This is the basic field pattern employed in the four-course range under discussion. Figure 3-95 illustrates this type of pattern. If to this one set of antennas radiating a figure eight pattern, another pair of antennas is added so that the axis of the two pairs is perpendicular and the power is applied alternately to one pair then the other, a cloverleaf-shaped pattern will result. There are four zones, 90° apart, about the station where the field strength of one antenna is equal to the field strength of the adjacent antennas. These zones are called **equisignal zones.** If a means is used to detect these zones, they can be used as courses or beams leading directly to or from the station. The basis of operation of all radio ranges is the equisignal zone which is detected to indicate courses for the pilot to follow. (Figure 3-96)

The straight lines leading away from the radio range stations are the equisignal zones formed by the overlapping of the two radiated figure eight patterns. An ingenious method has been devised to detect the equisignal zones. **One pair of antennas transmits the letter N, while the other pair transmits the letter A.** An aircraft flying in the quadrant containing true north, or in the opposite quadrant, will hear the letter N (dah-dit).

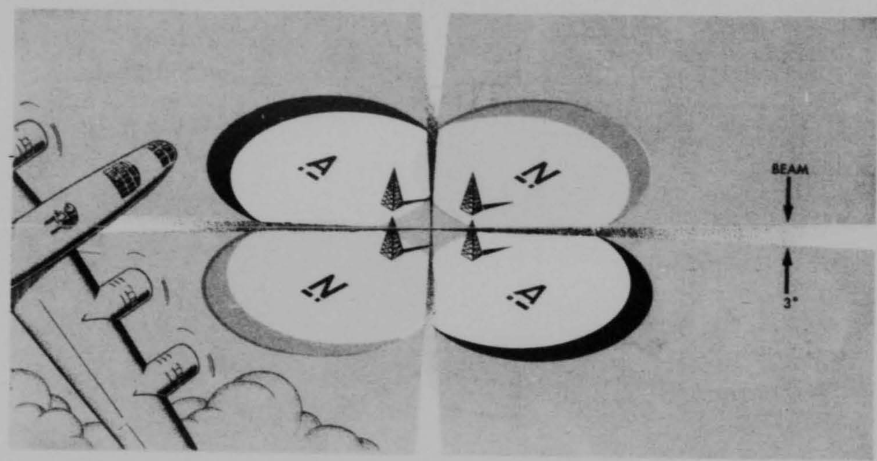


Figure 3-96 Radio Range Pattern

Aircraft flying in the remaining two quadrants will hear the letter A (dit-dah). The N and A are synchronized in such a manner that the dit of the A fits between the dah (—) and the dit (.) of the N, and the dah of the A fits between dah's of two N's. When both signals are received with equal intensity (at the equisignal zone), they blend to produce a continuous signal, indicating that the aircraft is on course. The equisignal zone, which is the course or "beam," is actually about three degrees wide. (Figure 3-97)

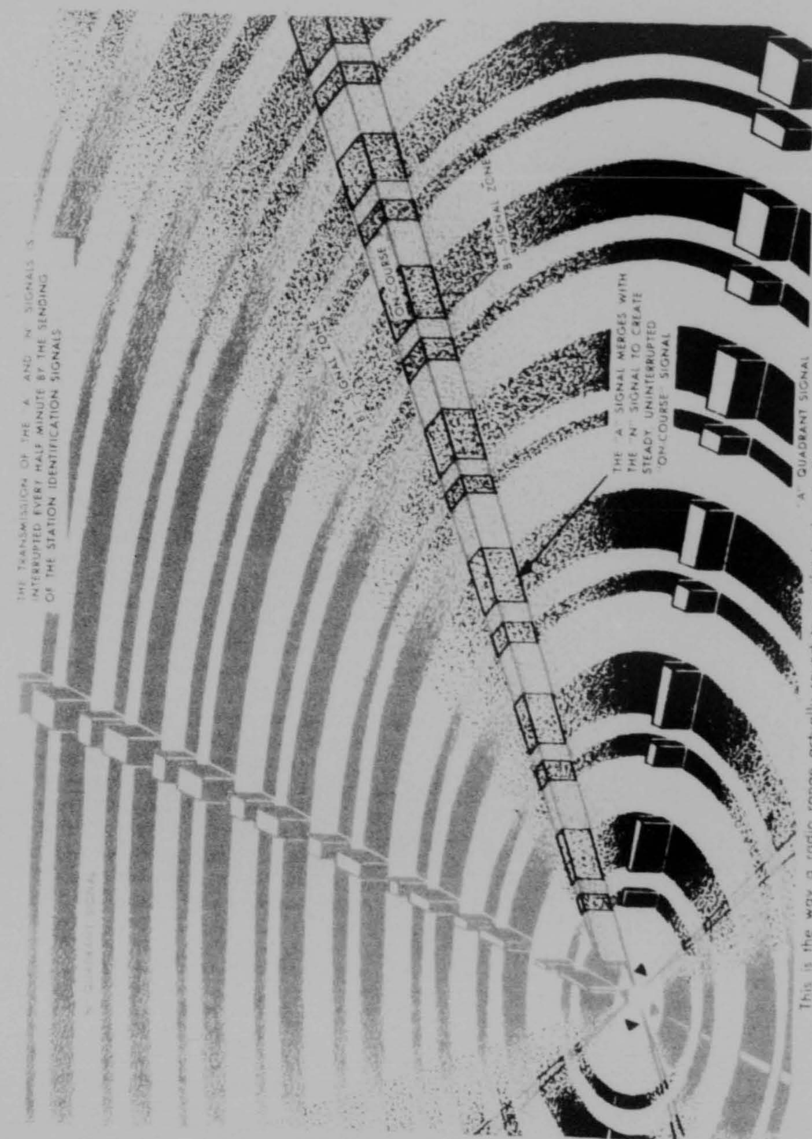
The quadrant containing the true bearing of 180 toward the station is the N quadrant for all ranges operated by the United States government. The opposite quadrant is also an N quadrant. When the north leg and true north line coincide, the N signal is transmitted in the northwest quadrant.

On either side of the course, there is an area where both the A and N signal may be heard. These signals are not heard with equal intensity, but depending on the location of the aircraft, the A is heard with greater intensity than the N or the N is heard with greater intensity than the A. The area on either side of the course where both the A and the N can be heard, but with different intensities, is known as the "twilight zone."

Directly above the radio range station, there is an area in which little or no signal is radiated. This area is known as the **cone of silence.** (Figure 3-98). When an aircraft is in this area, little or no signal is received, and it serves as a check point for the pilot indicating that he is directly over the station. The cone of silence is a great aid to the pilot, since it enables him to pin-point his location at that instant.

In the previous discussion, all the courses for the radio range station have been considered as being at right angles to each other. In actual practice, however, it is often desirable that the radio range courses parallel those of established airways and therefore all courses will not be at right angles. Within certain limits, however, these beams can be adjusted to furnish any desired course alignment. The courses are not independent of one another and consequently the readjustment of one course requires the readjustment of all the other courses. The courses are shifted by squeezing or rotated by bending.

"Squeezing the courses" means varying the angle between the courses, but maintaining the reciprocal course relationships. In other words, it is a rotation of one pair of courses electrically while opposite courses



This is the way a radio range actually sound to a pilot in the air. The tone gradation of each A or N signal indicates the relative intensity with which those signals are heard.

Figure 3-97 Radio Range Signal Pattern

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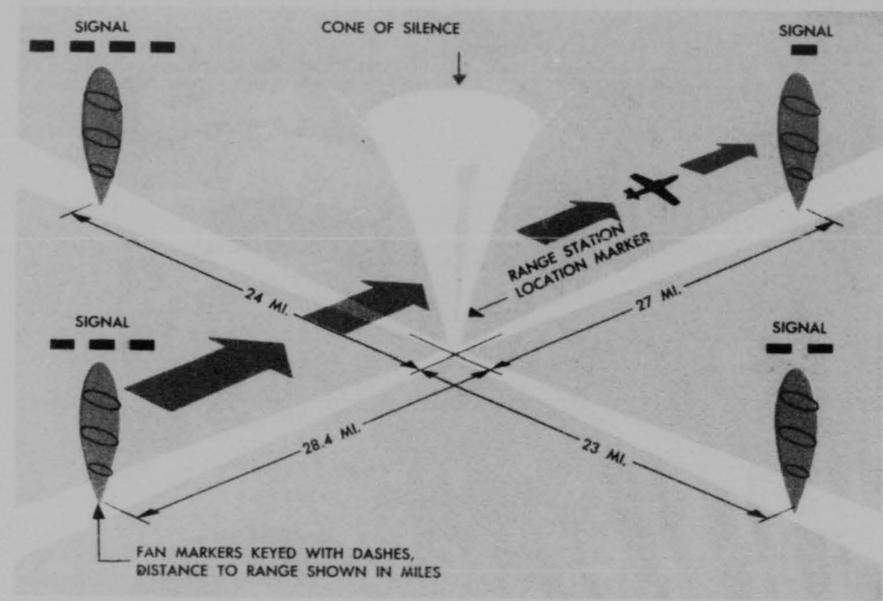

Figure 3-98 Cone of Silence and Fan Markers

still go straight through the station.

"Rotating the course" means moving all the courses an equal number of degrees in the same direction. If all the courses are to be moved, the same number of degrees in the same direction, the antenna could be rotated. In some types of equipment this is actually done; but the rotation of the courses can be accomplished effectively by electrical means without changing the physical position of the antennas.

"Bending of the courses" means varying the reciprocal relationships of the diagonal courses. This is done when it is necessary to bend a pair of opposite courses so they do not lie in a straight line. Each radio range is assigned an individual two- or three-letter identification sign or call sign. The cycle of A and N signals is interrupted every thirty seconds and the identification of the station is alternately transmitted over the antenna systems, first over the N antenna and then over the A antenna. In the twilight (bi-signal) zone, both identifications will be heard but with different intensities. It is extremely difficult for the human ear to distinguish between relative intensities of two signals interwoven with each other, as in the case of the A and N signals. Therefore, when flying in the twilight zone, the usual procedure is to listen to the station identification which is transmitted with distinct breaks, and by comparing the relative intensities of these two signals against the background of silence fly a reasonable accurate course in a twilight zone.

Adcock Radio Range. The Adcock radio range system receives its name from the type of antenna system employed. The Adcock antenna is a vertical antenna system emitting only vertically polarized waves with the major portion of the radiation confined to the lower part of the atmosphere. The Adcock range is normally a simultaneous-type range. The term simultaneous-type range derives its name from the fact that it can transmit radio range signals and voice communications at the same time. Both signals can be heard at the same frequency setting of the receiver.

Two radio transmitters are employed in this system. One is known as the "range transmitter;" the other is called the "carrier transmitter" and transmits the voice communication. The output of the range transmitter goes through a coupling unit where all squeezing, rotating, and bending are accomplished, and then to the antenna system. The two transmitters operate continuously and simultaneously. The range transmitter emits an unmodulated signal, and when employed alone, will not produce a tone in the receiver tuned to its frequency. The carrier transmitter may be voice modulated when voice transmissions are desired but is unmodulated at all other times.

The audio tone which is heard in the radio receiver is created by the beat note between the frequencies of the two transmitters. The carrier transmitter has a frequency which differs by 1,020 cycles from the frequency employed in the range of the transmitter. For example, when the transmitter is operating at 300 kcs, then the range transmitter will be operating at 301.020 kcs. Since these frequencies are so close together, both will enter the receiver and produce a 1,020 note. In effect, the carrier transmitter modulates the range transmitter approximately 30 per cent of the time, while the remaining 70 per cent is for the voice modulation. Most of the audible portions of the male speaking voice are in the lower portion of the voice band from 200 to 3,000 cycles. There is comparatively little voice energy at 1,020 cycles so the speech and tone do not interfere greatly with one another when both are received. A filter is contained in the receiver, however, which permits the operator to select any one of three positions and the desired mode of reception. He may choose to receive the voice communications alone, or the radio range signals alone, or receive both at the same time.

The radio range radiation takes place from the four antennas at the corner of the square as shown in Figure 3-96. The carrier transmitter transmits from a single vertical tower located in the center of the square and with equal intensity in all directions. Thus, the carrier transmitter may be employed, in addition to voice communication, by a radio compass at any direction from the station.

Adcock radio ranges are designated as full or medium power ranges in the Radio Facility Charts. Full power ranges are rated at 150 watts or more and have an effective range of about 100 miles. These carry the designation of RA. Medium power ranges are designated by MRA and have a power output from 50 to 150 watts and an effective range of about fifty miles. In both instances, the A indicates Adcock ranges. Maximum ranges of 600 miles over water are possible but the beam is too wide for navigational purposes; radio ranges normally employ frequencies between 200 and 400 kcs. The Adcock range is relatively free from night effect and all courses are stable and have a relatively constant useable range, day or night. They have a good cone of silence at all heights above the range station. On the other hand, the antenna equipment is bulky, and the installation is a major construction job. Skilled personnel and several weeks' time are required to install, calibrate, and align the range.

Loop-Type Radio Range. The principle involved in the loop-type radio range is the same for the Adcock radio range. However, the loop-type radio range employs only a single transmitter. This transmitter is modulated by a 1,020 cycle note in order to obtain the range information. If voice transmission is desired, it is necessary to shut down the range. This system is not a simultaneous range. Normally, the same transmission is employed for either range or voice transmission with a nondirectional antenna being used for the voice transmission. When a parasitic antenna is employed to produce course bending, this antenna may be used for the voice transmission.

Loop-type ranges have little if any advantage for long distance night operation, since the horizontal portion of the antenna causes a large horizontally polarized radiation which results in a strong night effect. A vertical antenna less than a quarter-wave high has a low angle of radiation, while a horizontal antenna less than a quarter-wave high has a high angle of radiation. This high-angle radiation component of the loop is refracted by the ionosphere and may be as strong as the vertical component when received at the aircraft. As a result, the equisignal zone of the loop-type range may swing erratically and sometimes fade altogether. Loop radio ranges have been responsible for many flying accidents. Reliable ranges at night are not over thirty miles, regardless of power. In addition to night effect, the loops are subject to swinging in high winds causing the radio beams to swing. Also, the cone of silence is not as well defined at higher altitudes as the cone of silence above the Adcock range stations.

Marker Beacons. In addition to the radio range equipment, there is usually a system of marker beacons used in connection with the radio range system. Definite fixes are not possible with the radio range equipment, except when passing directly through the cone of silence, and in some instances, particularly with loop-type radio ranges, the cone of silence is ill-defined, even indistinguishable, at higher altitudes. For this reason, marker beacons are used to aid the pilot in finding his exact position on the beam or over the station.

Fan marker beacons are very-high-frequency radio transmitters, installed at some distance from the radio range station, which transmit a fan-shaped pattern across the radio range beam. These fan marker beacons operate on a frequency of 75 mcs. and emit a signal which is received and presented visually in military aircraft. These signals are keyed to conform with the numbers assigned to the on-course signals across which they are located. Fan markers are keyed clockwise from true north to identify the course in which they are located. The first fan marker clockwise from true north is keyed with one dash, the second with two, the third with three, and the fourth with four dashes (Figure 3-98). Passing over a fan marker definitely establishes the position of the aircraft. At times, fan markers are installed at distances from two to four miles from the airfield on the leg of the course passing over the field, which facilitates instrument approaches. These fan markers are in addition to those installed at greater distances from the field. The signals emitted by the fan marker, their names, and the distances from the marker to the radio range stations are shown in the Radio Facility Charts.

Station markers, or Z markers, are installed at some radio range stations. These markers also operate on a frequency of 75 mcs. but are not keyed. They emit a steady signal vertically into the cone of silence and thus definitely establish the location of the cone of silence above any given radio range station. Z markers are employed in those cases where, due to the effects of terrain, the cone of silence is poorly defined or entirely lost. For air navigation, it is necessary to be able to pin-point the locations of the radio range stations so that the pilot knows exactly where he is in space.

VHF Radio Ranges. The same basic principles of operation apply to the VHF ranges as well as to the ranges previously discussed. However, the courses or beams of the VHF radio ranges projected along established airways are visual courses, while the courses projected across the airways are aural courses.

Ideally, radio range reception should be visual, not aural. The pilot needs his ears to receive airways communications, as well as traffic control instructions. In addition, he must listen to weather broadcasts, and keep alert for special messages which may be transmitted to all pilots over the CAA communications system on the same frequency as the radio range. Even when accompanied by a co-pilot, the pilot still does not have enough ears to hear simultaneously everything that he is supposed to hear. From the practical piloting point of view, it is essential to have course indication interpreted visually, not aurally.

Figure 3-99 illustrate the basic principle of a horizontally polarized two-course VHF radio range called the **visual-aural range** (VAR). The course identification signal, transmitted to the north or to the south (or to the west or to the east) is respectively either the D or the U signal in the Morse code, the equi-signal zone delineating the course, or a set of two audio frequencies suited for either aural or visual interpretation, similarly transmitted. Every thirty seconds, the range course identification sig-

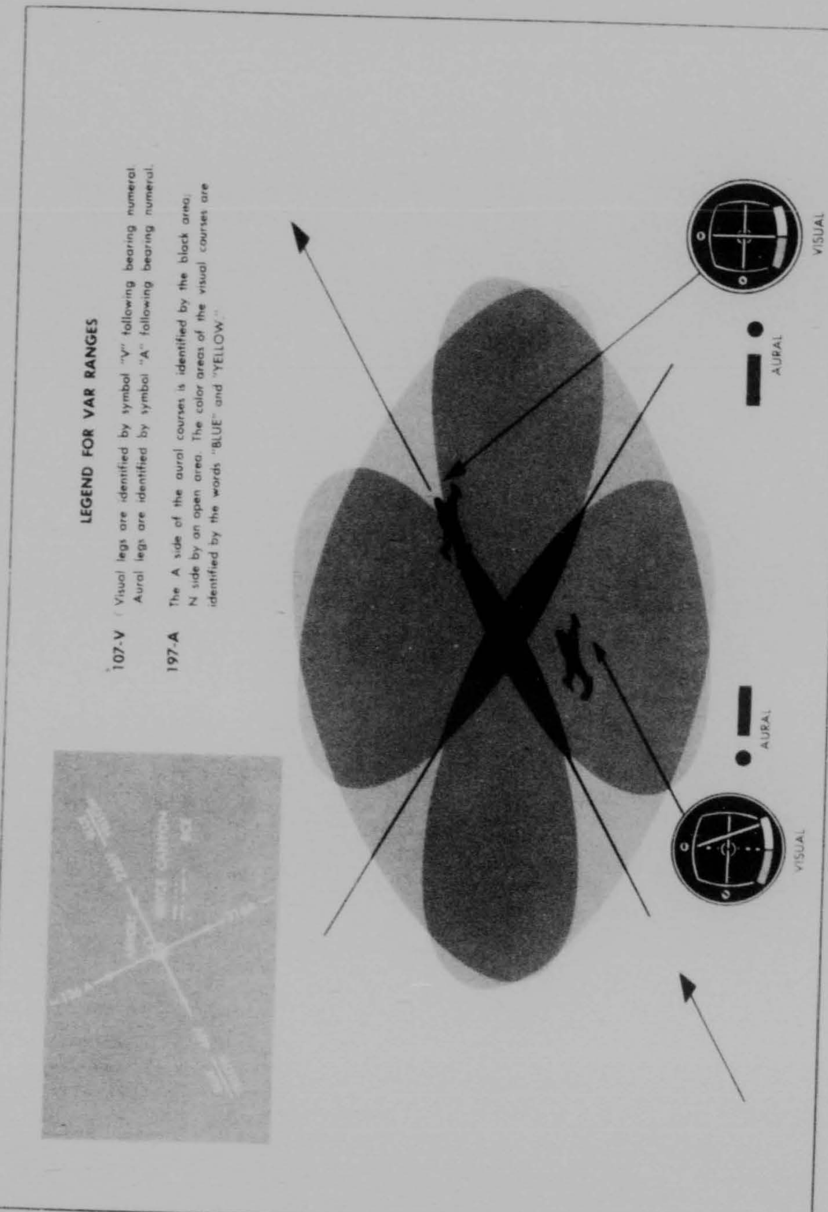

Figure 3-99 Two-Course Radio Range

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nals are interrupted, and a special antenna array (physically a counterpart of the course transmission array but at right angles to it) transmits the station identifying signal—first to the north or to the west, then to the south or to the east—followed by the letter N or S if the course lies primarily to the north or south, or the letters W and E if the course lies primarily to the west or east with respect to the transmitting station. Thus, in addition to the course identifying signals, and the station identifying signals, the radio range will also transmit directional information showing the pilot at once his direction with respect to the radio range station.

Since the ear cannot compare the intensity of the two signals employed for visual course, two filters are arranged in the receiver which will pass the 90- and 150-cycle frequencies' separately. Each of the modulation frequencies is then fed to a single meter whose needle normally rests at the center scale. When the 90 cycle frequency, which represents the A signal, is stronger than that corresponding to the N signal, the meter will deflect to one side. When the radio is reversed it will deflect in the other direction. Thus, a single meter indicates the quadrant signal and its amount, relieving the pilot of the necessity for the use of a headset.

The VHF Omnirange (VOR) is a radio aid to air navigation which furnishes definite track guidance between the range station and any point approximately fifty miles away when flying at a minmum instrument altitude in accordance with local terrain. The distance increases with altitude ranging at 150 miles for 14,000 feet.

Just as in the two-course visual-aural VHF range and the VHF runway localizer, the course is defined by the movement of a cross-pointer instrument in the aircraft. The distinctive feature of the omnirange is that the orientation of the course is under the control of the pilot without limitation as to azimuth.

Three basic instruments are used by the pilot to fly these ranges. The first is the aforementioned cross-pointer which indicates to the pilot his position relative to the desired course. The second is the azimuth selector, the dial face of which is similar in appearance to that of the automatic direction finder. The pointer of this instrument is rotated by means of a knob which serves as a manual course selection control. When the cross-pointer needle is centered, the position of the azimuth selector pointer indicates the magnetic bearing of the aircraft either to or from the station. The third instrument is a sense indicator described later.

In operation, the pilot selects a course by setting the pointer on the azimuth selector to the desired magnetic bearing and then flies that course by reference to the cross-pointer instrument. As in the navigational aids named above, this facility also has a reciprocal course. The sense indicator is similar in appearance to the ordinary panel meter but is mounted so that the pivot needle is at the left side of the case rather than at the bottom.

After a course has been selected and the sensing determined, the aircraft is always flown in the same direction as the deflection of the vertical cross-pointer indicator needle.

For example, if the aircraft is due south of the station, and it is desired to fly to the station, the azimuth selector is set so that the pointer reads zero degrees. For this condition, the sense indicator will point to the word "TO" indicating that the station is in front of the aircraft. (See Figure 3-100)

If a pilot wishes to determine his position in flight, he may tune his receiver to one station in his general area, rotate the azimuth selector until the vertical needle of the cross-pointer instrument is centered, and then note the azimuth selector bearing. By repeating the procedure with a second station, a fix can be taken. Each range is identified by a three-letter coded signal which is transmitted on the omnirange frequency.

VHF radio ranges have the same general characteristics of other VHF equipment: line-of-sight propagation and freedom from atmospheric noise. Any pilot can use the VHF radio range as an aid to navigation if the aircraft is equipped with the specialized receiving equipment used with the USAF instrument approach system. (IAS).

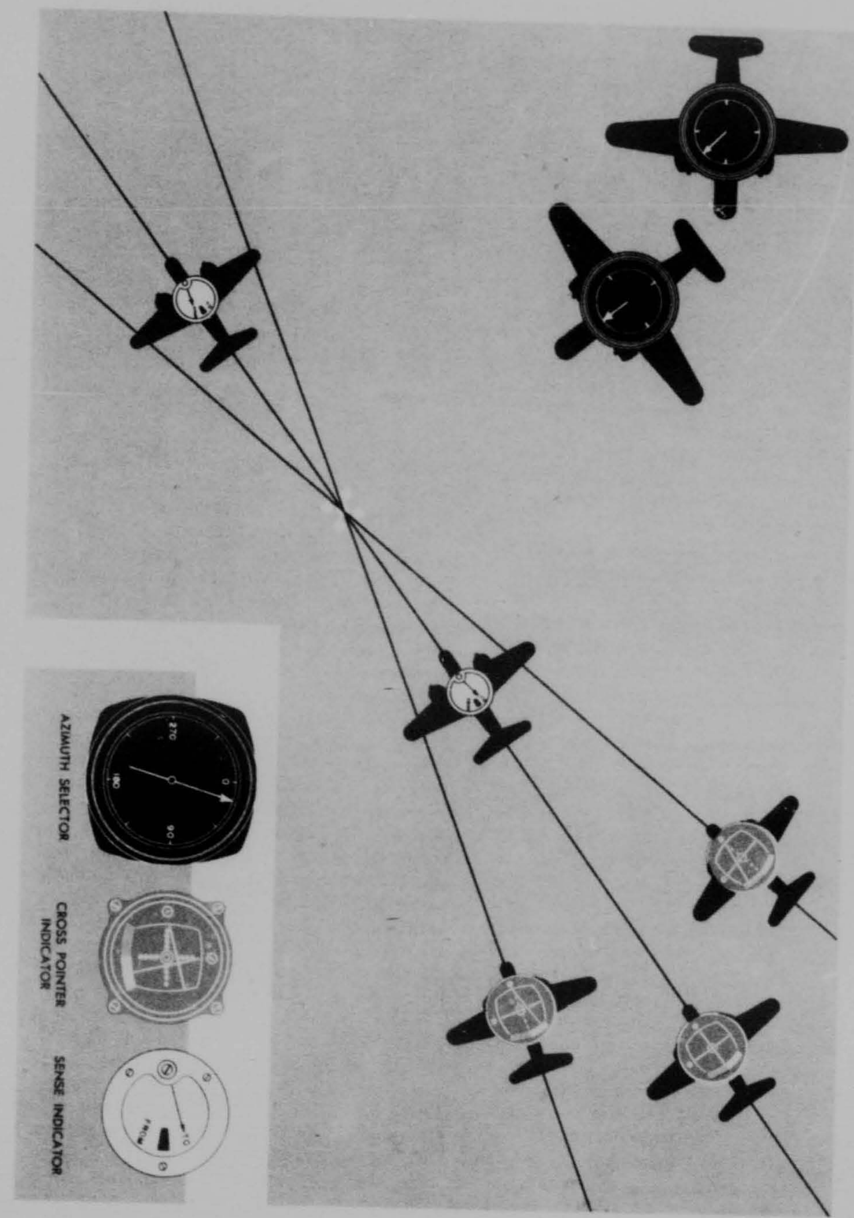

Figure 3-100 VHF Omnirange

Radio Compass

Valuable as the radio range is as an aid to navigation, it does not enable the pilot to determine his exact position, since it only furnishes a single direction and does not supply information concerning distance. In order to be able to establish his position, a pilot must have the direction and distance from a known object or the direction from two known objects. The radio compass is a device that may be employed in this manner.

Everyone is familiar with the fact that most ordinary portable radios will pick up radio broadcasts with a varying degree of volume, depending upon the position in which the set itself is placed. That is, reception will fade or build up in volume as the set is turned around. This characteristic is exhibited because most sets are equipped with a simple loop antenna built directly into the case. Loop antennas, even in this simple form, have definite directional characteristics. These characteristics are:

When the plane of the loop is parallel to the path of the radio wave, a maximum signal will be obtained.

When the plane of the loop is perpendicular to the path of the radio wave, a minimum signal will be obtained.

These directional characteristics of a loop antenna are utilized for navigation and other purposes in the modern, highly efficient loop antenna installed in USAF aircraft.

Like the antenna of a portable radio, an aircraft loop antenna picks up signals at maximum strength when the windings of the loop are parallel to a line drawn from the transmitting antenna to the loop (the edge of the loop is pointed toward the station). Minimum signal strength is picked up when the plane of the loop is perpendicular to this line. The position of minimum signal strength is known as a "null" position. A small change in the direction of the loop near a null position will cause a relatively large change in the received signal strength, while the same small change in loop direction near the maximum position will cause only a small change in the received signal strength.

In other words, the null position of the loop is sharply defined and the maximum position is broadly defined. Consequently, for direction finding, the null position is used in employing the direction of the transmitting station.

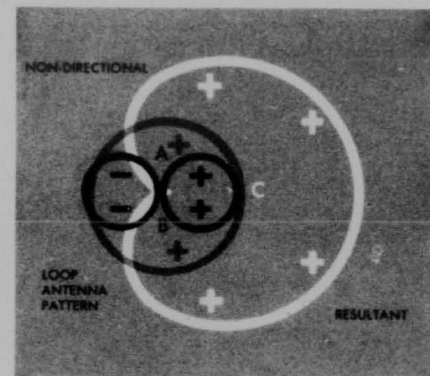

Figure 3-101 Sensitivity Pattern of Radio Compass

It will be observed that a single loop antenna is bidirectional, that is, the station may be in either one of two directions that are 180° apart. This is known as the 180° ambiguity of the loop antenna. It then becomes necessary for the pilot to solve the problem and determine the actual direction of the station.

However, the loop antenna system may be made unidirectional by the introduction of a sense antenna. With the aid of the sense antenna, the bidirectional loop becomes sensitive to the signals arriving from one direction only. The sense antenna is switched into the receiving antenna circuit, either by pressing the sense button (which automatically connects, in addition to the direction finding loop antenna output, the output of the nondirectional sense antenna), or by employing an automatic circuit which continuously gives unidirectional indication.

Figure 3-101 shows how the bidirectional properties of the simple aural-null loop antenna can be changed to a unidirectional sensitivity by the introduction into the antenna circuit of a nondirectional sense antenna. At A is shown the figure 8 pattern of a normally balanced loop antenna disposed vertically with respect to the ground. At B is shown the nondirectional sensitivity pat-

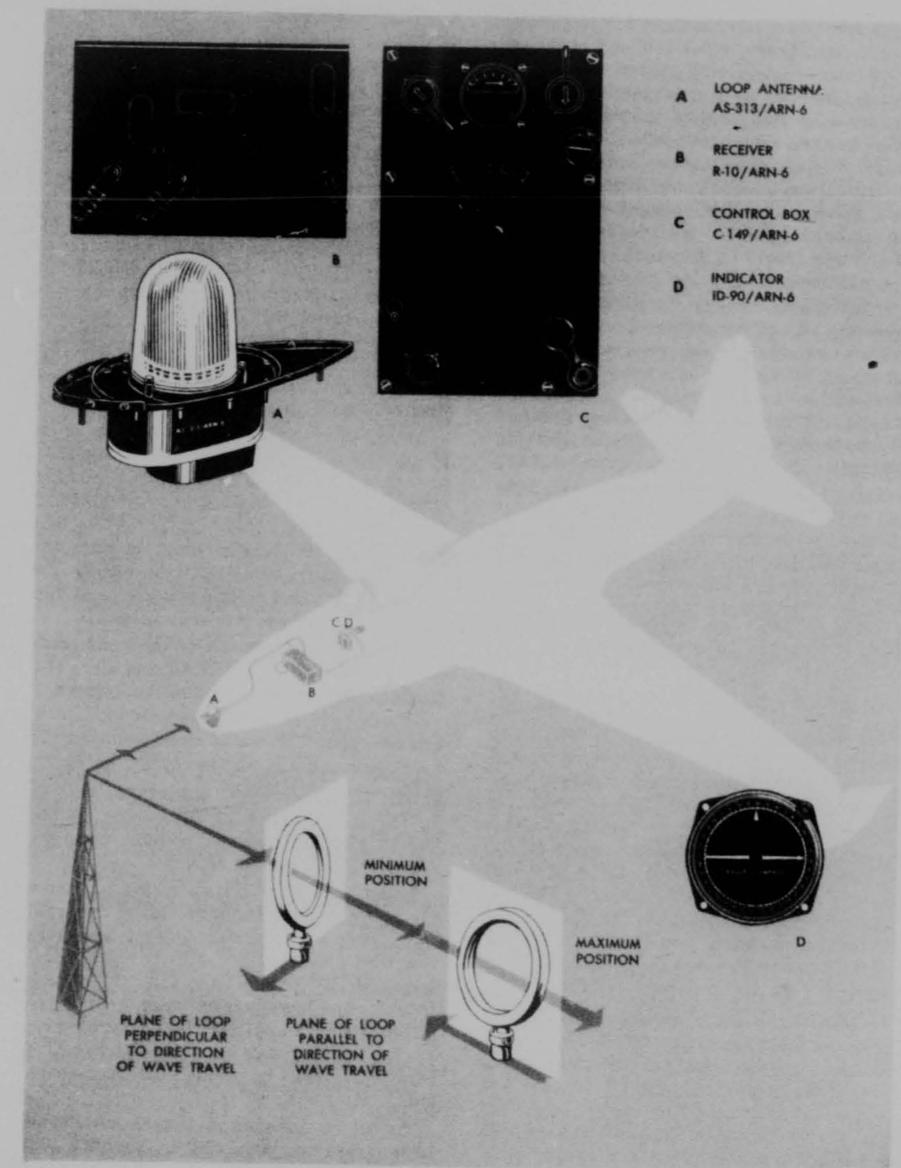

Figure 3-102 Radio Compass Installation and Operation

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tern of the sense antenna. When the signals from these two antennas are fed to the receiver simultaneously but 180° out of phase, the combined sensitivity pattern of both antennas assumes a heart-shaped (cardioid) pattern as shown at C in the figure. Thus, whenever the sense antenna's sensitivity is electrically added to the loop antenna's sensitivity, the combined sensitivity pattern of both antennas is aurally responsive only to signals arriving at right angles to the plane of the loop from one direction.

When installed in an aircraft together with a suitable receiver, fixed antenna, controll box and power supply, the directional qualities of the loop can be used for radio direction finding. The loop antenna receiver combination is called the radio compass, although the term "radio direction finding" also is used. There are three types of radio compass equipment employed by the USAF.

Fixed Loop with Left Right Indicator. The indicator employed with this equipment is centered when the loop is in the null position. The fixed-type loop radio compasses are still used in a small number of aircraft. However, the disadvantage of this type of radio compass is evident in that the aircraft must be headed toward the transmitting station in order to obtain a bearing.

Rotatable Loop with Left Right Indicator.

This is a later development of the fixed loop type in that the loop antenna may be manually rotated in order to position the loop on a null. An azimuth scale located near the loop rotating crank shows the longitudinal axis of the aircraft. The indications to the left right indicator are identical with those for the fixed loop type compass. When the left right indicator is centered, the loop is in the null position, and the needle of the azimuth indicator points to the relative bearing of the station from the aircraft.

Automatic Radio Compass. This type of radio compass equipment is the latest development, and currently the standard, in the USAF. When this equipment is used in the compass position, the loop automatically rotates to line up with the radio transmitter in the null position. A pointer turning upon an azimuth scale is synchronized electrically with the loop and indicates the position of the loop with respect to the aircraft, and thus the relative bearing of the radio station to which the radio compass is tuned.

The Aural Null. As stated previously, the null position of the loop antenna is indicated by the radio bearing indicator of the automatic compass, or by noting the reading on the azimuth scale when the left/right needle is centered in the case of the older equipment. Under some conditions, however, it is necessary to determine the null position without using visual indicators. The null position of the loop can be determined aurally by noting the minimum strength of the signals received in the headset, while the position of the loop is changed relative to the radio station. This minimum signal is termed the aural null. The terms "nose-null" and "wing-tip null" are defined as:

Nose Null. The hole in the antenna loop points toward the nose of the aircraft, and the aural null will be received if the radio station is directly ahead or directly behind the aircraft.

Wing-tip Null. The hole in the loop antenna points toward the wings of the aircraft, and a null will be received when the radio station is 90° to the right or left of the aircraft.

Figure 3-102 shows one of the radio compasses employed by the USAF and gives the technical data concerning that equipment.

Loran

Loran is the term for Long Range Navigation. It was developed during the war as an aid to navigation on over-water flights and to give the greatest possible accuracy consistent with maximum range.

Loran is a radio system which measures the time difference in the arrival of the radio waves from a pair of radio stations and from this time difference a line of position is determined. By obtaining a line of position from two or more station pairs, a fix is obtained giving accurately the actual location of the receiving station. Loran charts which carry these lines of position are used as an aid.

To better understand Loran, we should take an example as shown in Figure 3-103. Assume that two stations are 324 nautical miles apart which is 2,000 microseconds of

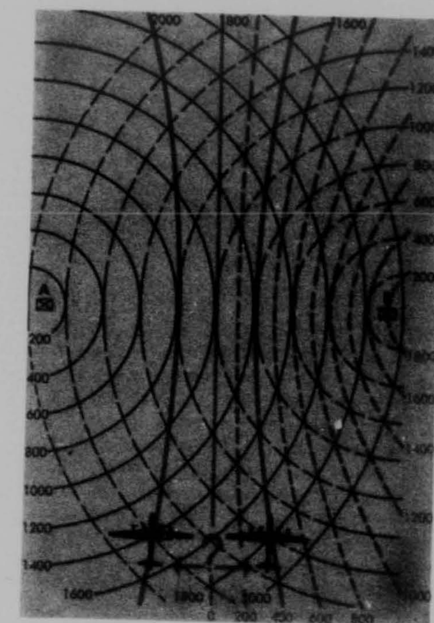


Figure 3-103 Simple Loran

radio time. First, let us assume that stations A and B are broadcasting at the same time. Dotted lines show points of equal time differences, and, as can be noticed, these time differences are the same on both sides of the zero (0) line. Thus, if an aircraft is on a time difference line of 400 microseconds, the pilot cannot know whether he is to the left or the right of the zero line.

This difficulty is removed in actual Loran practice by a method of pulse staggering which operates as follows: first, a "master" or A-type station transmits a pulse. After reception of this pulse, the "slave" or B-type station awaits a definite fixed amount of time plus another variable interval called the "code delay" before it transmits its pulse. As a result of this delay at all points within the area of coverage of the two stations used, the time interval between a master-station pulse and the next slave-station pulse is always greater than the interval between the slave-station pulse and the master-station pulse. This results in each time difference having a number of its own. (See Figure 3-104.)

Thus, if an aircraft were at the line of position marked with the cross shown in Figure 3-104, it would indicate that the Loran operator would have a reading of 2,600 microseconds time interval. In order to get a fix, the operator would need to obtain a similar reading from another station pair, and where the two lines of position cross, he would have his fix point.

Time measurement is made possible by the use of the cathode-ray tube measuring device that has been employed extensively in radar. The receiver operates in the medium frequency band and feeds a video signal to the indicator unit. The signal from the master station arrives at the aircraft first and is shown on the cathode-ray tube, then the signal from the slave station arrives and is shown on the same tube.

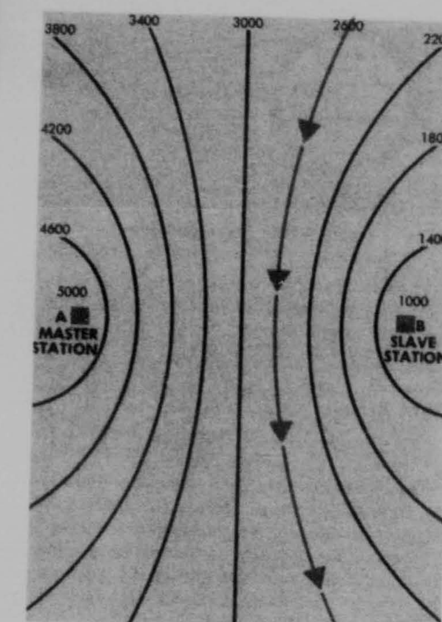


Figure 3-104 Actual Loran Practice

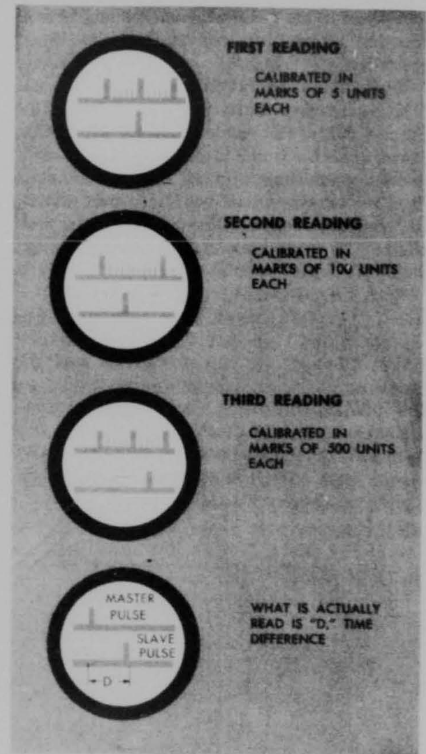


Figure 3-105 Loran Readings

Various readings are taken to give accuracy. A typical group of readings taken from the CRT might be:

First Reading	24
Second Reading	300
Third Reading	3,500
	3,824 microseconds

The operator can then measure directly the time difference in the arrival of the two signals. In addition to measuring this time difference, the operator is able to determine the identification of the station by reading the setting of certain dials on the face of the equipment. With this information, he is then able to refer to his Loran chart and determine the line of position upon which he is located. By repeating the process upon a second pair of stations, he is able to determine a second line of position and from this information to determine a fix.

The accuracy with which positions may be obtained by Loran varies with the location of the aircraft relative to the ground stations, and with atmospheric receiving conditions. In general, it is comparable to positions obtained by celestial observations. Errors of less than a half-mile may be expected in favorable locations and under good conditions; in unfavorable locations under poor conditions errors occasionally may exceed five or ten miles.

The effective range of Loran over sea water is about 600 to 700 nautical miles in the daytime and 1,200 to 1,400 nautical miles at night. This great range is achieved by the use of relatively low radio frequencies, just above the standard broadcast band, which can be propagated over the curvature of the earth.

The navigator can think of Loran as merely another method of determining line-of-position. These Loran lines may be crossed with other Loran lines, with sun lines, star lines, radar-range circles, or bearings to provide fixes. Loran lines are fixed with respect to the earth's surface; accuracy is not dependent upon the aircraft compass or chronometer, and it is not necessary to break radio silence to use Loran. Subject to the variation in range with time of day, Loran readings are possible at all times and in all weather conditions except during severe electrical disturbances, and they are almost as easy to make in rough air as in smooth air. A set of readings may be made and the position of the aircraft may be determined in three to five minutes under favorable conditions.

Loran is subject to enemy action and may be jammed. Such action can be detected and identified as intentional jamming by a well trained operator. The traffic handling capacity of the Loran system is unlimited. The system is entirely automatic and functions continuously. Therefore, any number of aircraft may use the system simultaneously without interference.

Special charts have been printed for use

in Loran navigation. They are on the Mercator projection and contain superimposed lines-of-position for the stations most likely to be received in the area covered by the chart. Each station's lines-of-position are in different colors and are marked with the microsecond reading if the aircraft is on that line-of-position. On most charts, the lines are separated by intervals of 20 microseconds. For any reading between these lines the navigator must interpolate by eye and draw his line-of-position.

High-frequency Direction-finding

High-frequency direction-finding (HF D/F) is another system provided to assist in navigating over long distances. This type of navigational aid is primarily for use with multiengine aircraft which carry a radio operator. These stations are, in general, used for providing fixes and courses to steer. The D/F nets consist of three or more stations placed in a line or semicircle that usually stretches some 600 miles in length and are located along the air routes. When in range of such a net, the pilot or radio operator may call in for a fix. The D/F operator then alerts the net and the aircraft is requested to send a series of dashes and call letters on which the D/F stations can take bearings. These bearings are then forwarded to an evaluation center for the purpose of plotting the bearings and determining the fix. At the evaluation center, the triangulation method is employed to determine the exact location of the aircraft. Three or more bearings are drawn on a map of the area covered by the net. Since these stations normally monitor aircraft frequencies, it often happens that they hear the request for a fix before the net is alerted and thus are able to send in the bearings before they are asked to do so.

The D/F service does not stop with the giving of a single fix or bearing. Often, the net tracks aircraft for hours, particularly when it is known that they are low on fuel or are disabled. In this way, the location of the aircraft is known at all times, and if the aircraft is forced down, rescue operations can be initiated immediately. Constant practice of all personnel involved in this operation is required in order to increase the efficiency of this system.

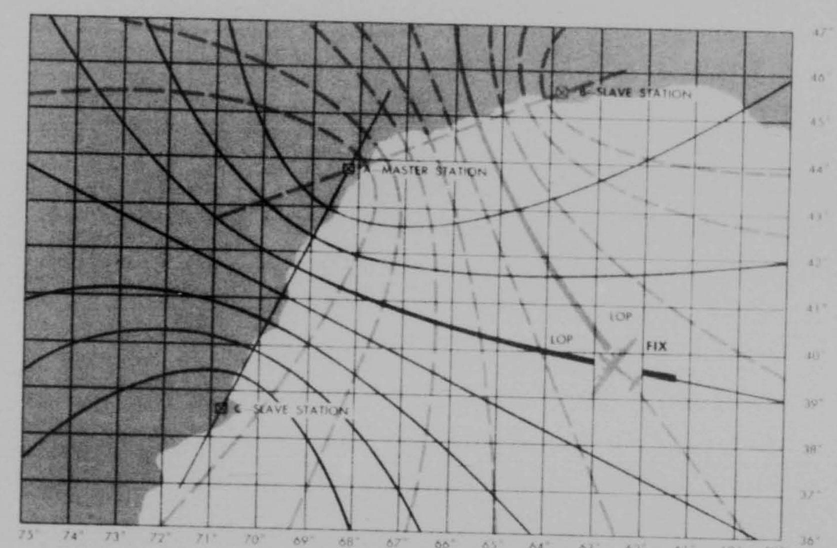


Figure 3-106 Loran Navigation Chart

The principle of operation of any direction-finding ground-based equipment is predicated on the use of a sensitive directional antenna, usually the Adcock type. The ground station manually, or electrically, turns the antenna until a null is obtained and the direction of the aircraft is determined. The same principles underlying the airborne radio compass are applied here.

A fair degree of accuracy may be expected from this system, roughly a ten-mile error at distances of 500 miles. The ranges of such a direction-finding system varies, depending on the time of day and the atmospherics conditions at any time. The range of an efficient system is approximately 1,000 to 2,000 miles. However, the system has inherent limitations. The fact that most of the transmissions must be Morse code makes it rather slow. The system is easily saturated since only one aircraft may use the system at one time. Also, it is vulnerable to enemy countermeasures such as jamming.

VHF Direction-finding

The VHF D F system operates on the same principles as the HF system. The paramount difference is in the use of the two systems. The VHF system is limited by the line-of-sight conditions under which it operates. Its primary use is with fighter aviation, since voice communication is employed between the pilot and the direction-finding station and because of the range limitation of the equipment employed.

Instrument Approach System

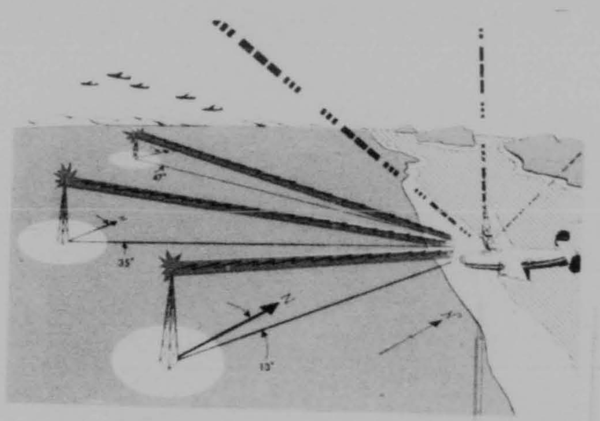
Facilities for the guidance of aircraft from point to point under adverse weather conditions have existed for a long time. Such facilities will guide the aircraft to the vicinity of the airfield but are not sufficiently accurate to bring the pilot close enough to the runway to land without visual reference to the ground. The USAF instrument approach system (Figure 3-108) consists of the radio transmitting and receiving equipment that furnishes the pilot with lateral and vertical guidance to the runway, and indication of distance away from the runway.

The system is used by multiengine-type aircraft provided with specialized airborne receiving equipment. All the indications to the pilot pertaining to his course glide path and distance to go are by visual means. Course and glide path information is presented on a two-pointer indicator; a vertical needle indicates the glide path. Present indication of distance is shown by an aircraft marker beacon light mounted on the instrument panel. This method provides the pilot with a series (usually three) of check points along the line of flight. Approaches to within fifty feet of the ground and at the rate of one aircraft every three minutes is considered possible for undamaged aircraft flown by experienced pilots and when a suitable means of controlling the aircraft to the point of entry on the glide path exists. No facilities are included for handling and stacking procedures.

The localizer transmitter, located at the far end of the runway, provides the signal that when received by the localizer unit located in the aircraft, give the pilot a **"fly right"** or **"fly left"** indication to keep his aircraft lined up laterally with the runway. The range of this signal is approximately forty miles at an altitude of 5,000 feet. The range of different installations of the localizing equipment may vary, depending upon the type of terrain over which the signal is transmitted, the condition of the transmitter, and the installation and condition of the receiving equipment.

The glide-path transmitter, located approximately 750 feet from the approach end of the runway and approximately 400 feet from the center line of the runway, provides (in conjunction with the aircraft receiving equipment) a "fly up" or a "fly down" signal to guide the pilot along a safe descent path to the ground. The range of the glide-path transmitter may vary under the same conditions as for the localizer transmitter.

Three marker beacon transmitting apparatus, one located near the approach end of the runway, one located approximately one mile from the approach end, and one located approximately four and one-half miles from the end of the runway provides the pilot with indication of his distance from the landing area. The marker beacon transmitters have a vertical range of approximately 3,000 feet.



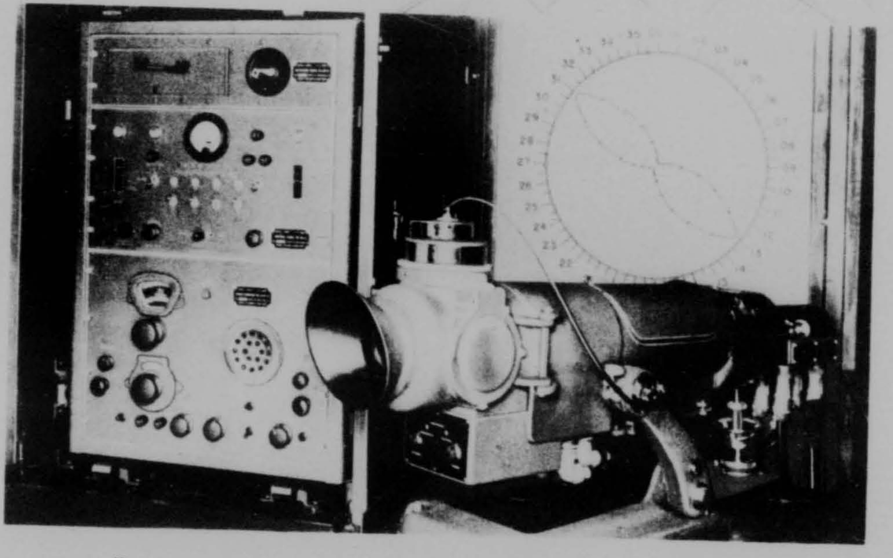


Figure 3-107 Radio Direction Finding Set, SCR-291

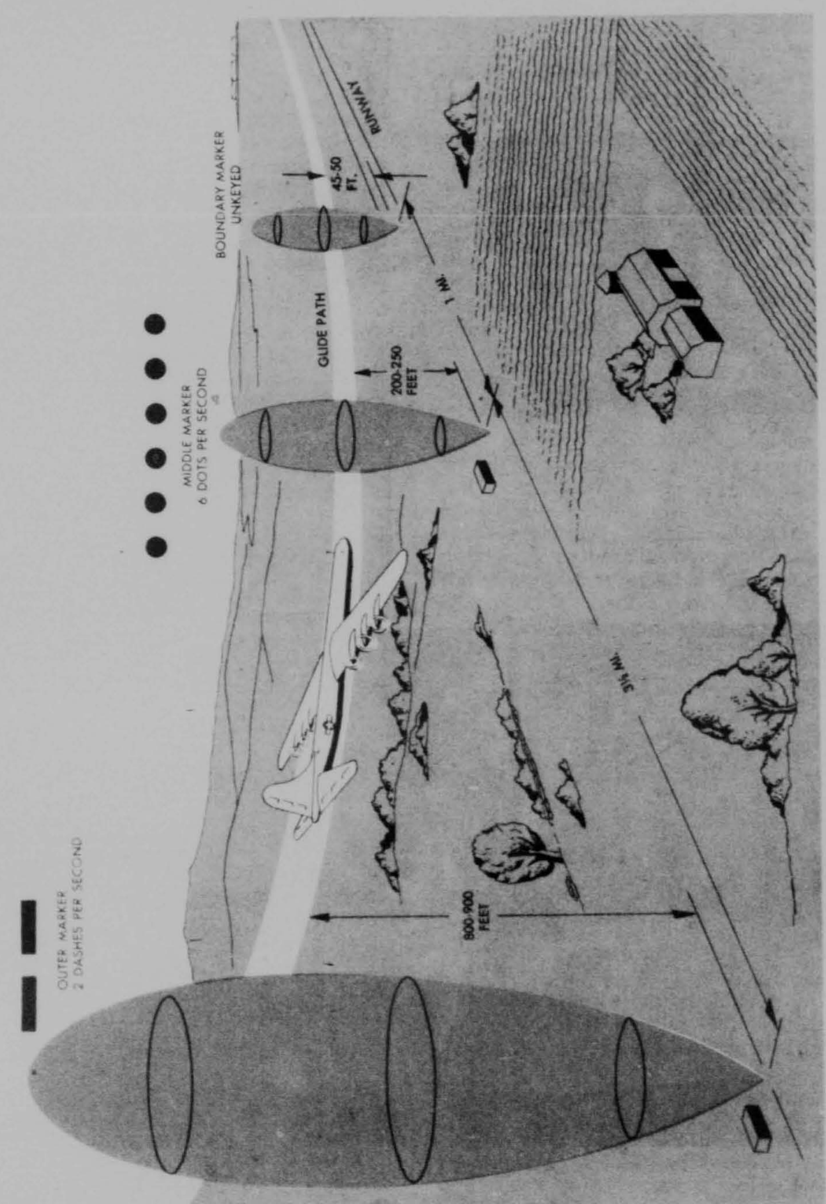


Figure 3-108 Glide Path and Marker Beacons

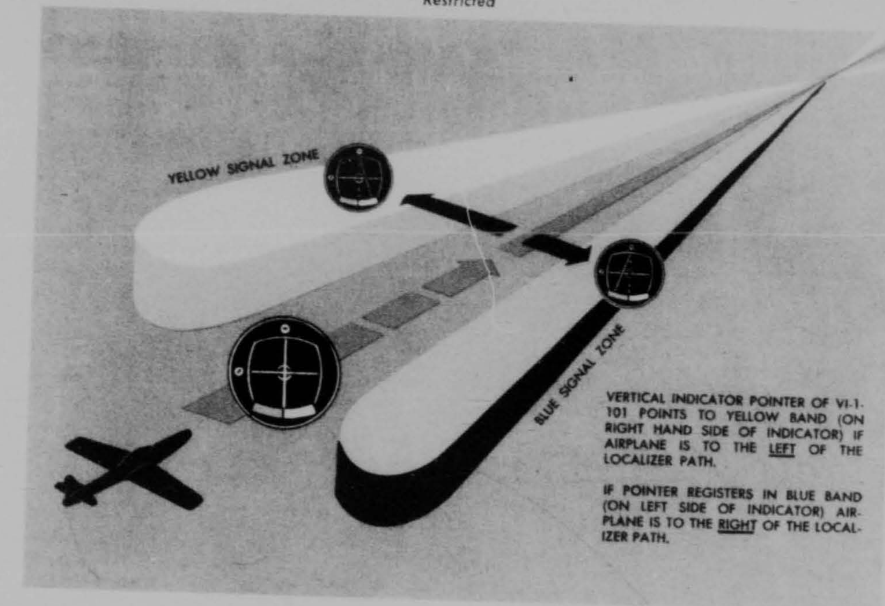


Figure 3-109 Indicator Operation with Glide Path Receiver

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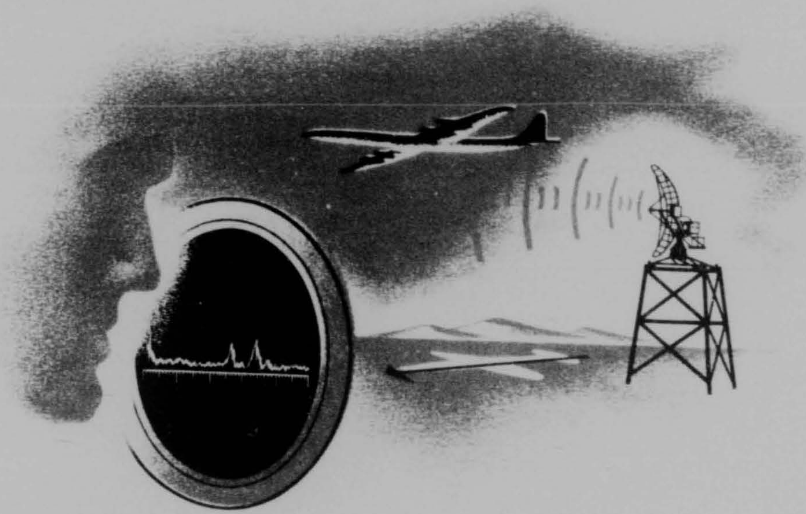
CHAPTER 4 - RADAR



SECTION 1 - HISTORY OF RADAR

1. GENERAL

Radar is a radiation device which may be used for detection and ranging of targets independent of time and weather conditions. It is properly studied under communications since it extends one of the senses of the commander—that of sight. It furnishes him with intelligence by permitting him to see some object that is not visible. The word "radar" is derived from the phrase RAdio Detection And Ranging.

2. HISTORICAL DEVELOPMENT

Undoubtedly, radar was one of the greatest scientific developments which emerged from World War II. Its development, like that of most other great inventions, was mothered by necessity—in this case, the necessity for offsetting an offensive weapon which made its first appearance in World War I, the military airplane. The basic principles upon which its functionings depend are simple and easily understood. Therefore, the seemingly complicated series of electrical events encountered in radar may be resolved into a logical series of functions.

Although the complete history of the origin and growth of modern radar is long and complicated, it is of sufficient interest to sketch here its main points.

Successful pulse-radar systems were developed independently in America, England, France, and Germany during the latter part of the 1930's. Behind the development lay more than fifty years of radio development for communication purposes, and a few early suggestions that, since radio waves are known to be reflected by objects whose size is in the order of a wavelength, they might be used to detect objects in fog or darkness.

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The fact that radio waves have optical properties identical with those of light was established by Heinrich Hertz in 1886 in the famous series of experiments in which he first discovered radio waves. Hertz showed, among other things, that radio waves were reflected by solid objects. In 1904, a German engineer, Hulsmeyer, was granted a patent in several countries on a proposed way of using this property in an obstacle detector and navigational aid for ships. In 1922, Marconi strongly urged the use of short waves for radio detection.

One of the first observations of radio echoes was made in the United States in 1922 by Dr. Albert H. Taylor of the Naval Research Laboratory. Taylor observed that a ship passing between a radio transmitter and receiver reflected some of the waves back toward the transmitter. By 1930 further tests proved the military value of this principle for the detection of surface vessels which were hidden by smoke or darkness. Further developments were conducted with carefully guarded secrecy. During this same period, Dr. Breit and Dr. Tuve of the Carnegie Institute at Washington published a report concerning their investigations of the ionosphere in which they first employed the principle of pulse ranging for measuring the height of the ionosphere. It is this principle which characterizes modern radar. After the successful experiments of Breit and Tuve, the radio-pulse echo technique became the established method for ionospheric investigation in all countries. In retrospect, the step from this technique to the idea of employing it for the detection of aircraft and ships is not a great one. The application was evolved by various individuals, acting independently and almost simultaneously in America, England, France, and Germany about ten years after the original work by Breit and Tuve.

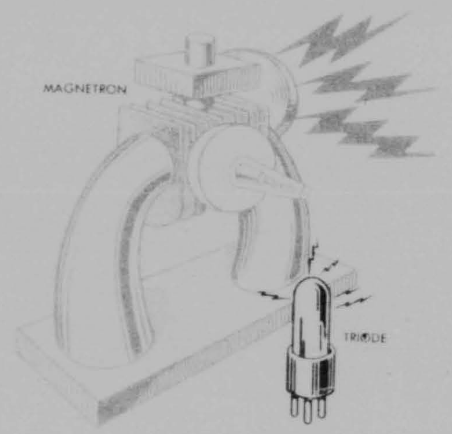
The United States military research agencies have a long history of early experiment, total failure, and qualified success in the field of radio detection. In early 1939, a radar set designed and built by the Naval Research Laboratory was given exhaustive tests at sea during battle maneuvers. Earlier, in November 1938, a radar position-finding equipment intended for the control of antiaircraft guns and searchlights, was designed and built by the Signal Corps Laboratories. This set underwent extensive tests and then went into production and became known as the SCR-268. The Air Force requested the Signal Corps to design and construct a long-range radar for the detection of aircraft. This set was successfully demonstrated in November 1939, with actual large-scale production getting underway in August 1940. This radio equipment became known as the SCR-270.

British radar was developed at about the same time but its application proceeded at a somewhat faster rate because of the pressure of war. The first experimental radar system of the type suggested by Sir Robert Watson-Watt was set up in the spring of 1935 on a small island off the coast of England. Development work during the summer led to the blocking out of the main features of the British early-warning stations by fall. Work began in 1936 toward setting up five stations about twenty-five miles apart to protect the Thames estuary. By March 1938, all these stations, the nucleus of the final chain, were complete and in operation.

British radar development then turned its maximum efforts to airborne equipment. Two types were first envisioned: a set for the detection of surface vessels by patrol aircraft, to be known as "ASV equipment," and an equipment for enabling night fighters to home on enemy aircraft, to be known as "AI" (Aircraft Interception). The first work was done on the ASV equipment and a successful demonstration made during fleet maneuvers in September 1938. Working models of the AI equipment were completed by June 1939 and successful demonstrations were made to the RAF Fighter Command in August. Four of these sets were installed and operating when the war broke out in September.

Emphasis on airborne radar brought out clearly that if sharp radar beams were to be produced by antennas small enough to be carried on aircraft, wavelengths shorter than the $1\frac{1}{2}$ meters used in the early British airborne equipment would have to be em-

ployed. This naturally led to the effort of developing a generator of microwaves which could give pulse power adequate for radar use. By early 1940, a British version of the multicavity magnetron had been developed to the point where it was an entirely practicable source of pulsed microwave energy.



In the fall of 1940, an early model of this magnetron operating on ten centimeters was brought to the United States for examination. The first American test of its power capabilities was made in October at the Bell Telephone Laboratories. This test confirmed British information and demonstrated that a generator now existed which was capable of supplying several times the power of the conventional triodes then in use and at a frequency four times greater. This point marks the beginning of modern radar.

The rapid progress of radar has been effected by free interchanges of information between the Americans and the British during the war. Under the pressure of war, the development of radar in seven years may be compared with the development of aircraft over a period of forty years.

Multicavity magnetron oscillators which will be discussed later, are now available for use in pulsed and continuous-wave generators at wavelengths from .5 to 50 centimeters. The upper limits of peak power now available are approximately 100 kilowatts at 1 centimeter, and 3 megawatts at 10 centimeters. The amount of peak power available for use decreases as the wavelength is decreased but improvements in magnetron design have been steadily pushing the amount of peak power available to higher values. Magnetrons may have operating voltages from about 1 kilovolt to 40 kilovolts. The magnetic field essential to operation ranges from 600 to 15,000 gausses. Tunable magnetrons are now available for many portions of the microwave band.

The effectiveness of radar as both an offensive and defensive weapon is already generally known, but some of the most salient features may bear repeating.

The British early-warning chain of radar stations is credited with having saved that country during the German blitz warfare in late 1940. Its tactical employment permitted a small RAF fighter force to be used at its greatest efficiency. The radar system allowed the aircraft to remain on the ground until approaching enemy aircraft were detected, then the fighters could be sent into the air to meet the enemy. The employment of an aircraft warning system of this type enabled the RAF to withstand the assaults of a numerically greater air force. If the method of maintaining aircraft on constant air patrol had been employed, it would have required many more pilots and aircraft than the British had available for the task. The use of radar permitted the planes to be serviced and the pilots to rest during periods of inactivity.

At first, radar was envisioned as a defensive weapon, but as the war progressed it came to be used for offensive purposes. By the end of May, 1941, radar had been employed to track aircraft automatically in azimuth and elevation and later to track the target automatically in range. This was the prototype of the antiaircraft position finder. The equipment for this purpose later became known as the SCR-584 and the SCR-545.

Further advancement in the field of air-

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borne radar permitted the development of sets that could be employed for long range navigation through overcast skies and the carrying out of strategic bombing missions in all kinds of weather. The technique of radar bombing was developed which permitted the bombardier to hit his target even though it was not visible to him. These developments gave the Air Force the ability to perform its job on an around-the-clock basis in all kinds of weather—an essential feature in successful military operations.

Gunfire-control radar developed as rapidly as the other types of radar. The Navy had success in destroying enemy shipping and naval forces with radar-controlled guns. However, the development of fire-control radar was not confined to surface equipment. The same principles were employed in making airborne gun-laying equipment.

Radar, both airborne and ground, has made a lasting impression on military tactics and will find an important place in the defense scheme of the nation and in any future military operations. Its employment in civilian aviation is still uncertain since the equipment is expensive and requires experienced personnel for operation and maintenance. In 1946, Signal Corps research workers received echoes from the moon with an SCR-271 radar.

Radar is being employed extensively in marine navigation, particularly in large, crowded harbors, such as those of New York and San Francisco.

SECTION 2 - PRINCIPLES OF RADAR

1. DEFINITION

Radar is the application of radio principles for detection of objects in space. In order to understand radar, it may be pertinent to use a familiar analogy.

2. GENERAL PRINCIPLES

Radar operates on a principle that is very similar to the reflection of sound waves. If a person shouts towards a cliff or some other sound-reflecting surface, he will hear the shout return from the direction of the cliff. What actually happens is that the energy in the sound wave travels through the air until it strikes the cliff where some of the energy is absorbed and the remainder is reflected back in the direction from which it came. Since some time elapses between the shout and the returned echo, it is possible to measure the distance of the object. Sound travels through air at approximately 1,100 feet per second. If a person shouts and it takes four

seconds from the instant he shouts until he hears the echo, he will be able to calculate that he is 2,200 feet from the object. The sound takes one half of the elapsed time to travel the distance to the cliff and the other half to return. Therefore, one half of the total time multiplied by the velocity of sound will give the distance to the object.

The distance to the object, however, is not the only consideration; to be able to determine the location of the object in space, it is necessary to know the bearing and altitude of the target as well as the distance from the observer. If a directional device is built to transmit and receive the sound waves, it then becomes possible to determine the direction and height of the object as well as the distance. A source of pulsating sound, at the focus of a parabolic reflector, is so arranged that it transmits a parallel beam of sound waves. The receiver is a highly directional microphone located inside a reflector to increase its directional effect. The microphone may be connected to an amplifier and a loudspeaker. It is assumed that the distance between the transmitter and the receiver is negligible when compared to the distance to the cliff.

To determine the distance and direction, the transmitting and receiving apparatus is placed so that the line of travel of the transmitted sound wave and the received echo coincide. The apparatus is then rotated until the maximum volume of the echo is received. The distance to the cliff can then be determined by multiplying one-half of the elapsed time in seconds by the velocity of sound. This will be the distance along the line RA. If the receiver apparatus is equipped with a circular scale marked in degrees and has been properly oriented with respect to north, the bearing or direction of the cliff may be determined. Thus, if the bearing is 45°, the cliff lies northeast of the receiving position.

To determine altitude (Figure 4-2), the transmitter and receiver are elevated from the horizontal position while aimed in the same direction. At first, the echo is still heard but the elapsed time is increased slightly. As the angle of elevation is increased further, a point is found where the echo disappears. This is the angle at which the sound wave is passing over the top of the cliff and therefore is not being reflected to the receiver. The point at which the echo disappears is that where the angle of elevation is such that the apparatus is pointed at B. If the receiving apparatus is equipped with an elevation scale, the angle of elevation may be determined as well as the distance RB. With this information, it is possible to determine the distance RA and the altitude AB. However, the altitude AB is the altitude above the transmitting station.

3. OPERATING PRINCIPLE

All radar equipment operates on a principle very much like that just described for sound waves. In radar equipment, a radio wave of extremely high frequency is used instead of a sound wave.

The energy transmitted by the radar equipment is similar to that transmitted by an ordinary radio transmitter. The radar has one outstanding difference in that it detects its own signals. It transmits a short pulse of radio energy and then rests for a short period of time waiting for a signal to return. This cycle of transmitting and waiting is repeated from 60 to 4,000 times per second depending upon the design range of the equipment. If there is no object in space for the outgoing energy to strike, it simply travels on out and is lost.

If, however, the wave strikes an object such as an aircraft, a ship, a building, a hill, or a cloud, some of the energy will be returned as a reflected wave or an echo. When the object in space is a good conductor of electricity and is large, as compared with a quarter-wavelength of the transmitted radio energy, a strong echo is returned by the object. However, if the object is a poor conductor of electricity or is small when compared with a quarter-wavelength of the transmitted radio energy, the returned echo will be weak. When radio energy strikes an object possessing the proper characteristics, some of the energy will be reradiated. In effect, the object becomes a source of radio energy or a parasitic transmitter. The atmosphere itself may cause reflection under conditions similar to those discussed in con-

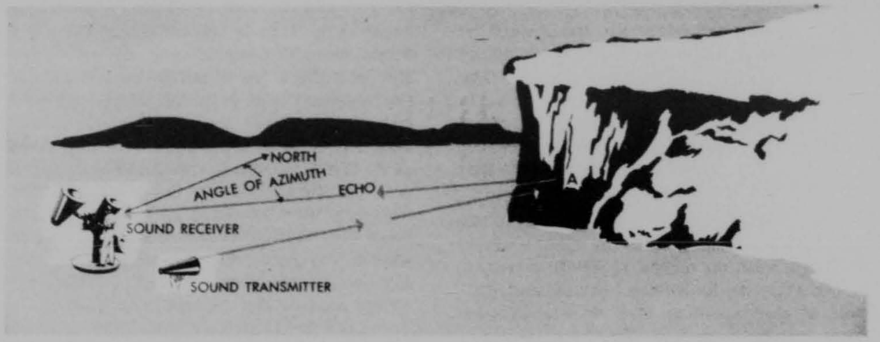

Figure 4-1 Determination of Direction

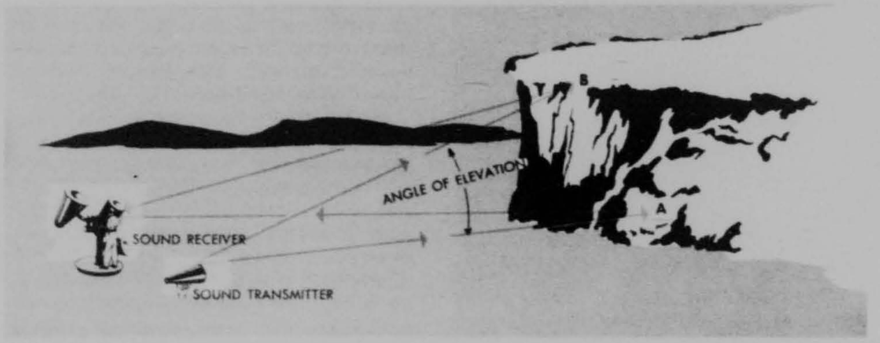

Figure 4-2 Determination of Height

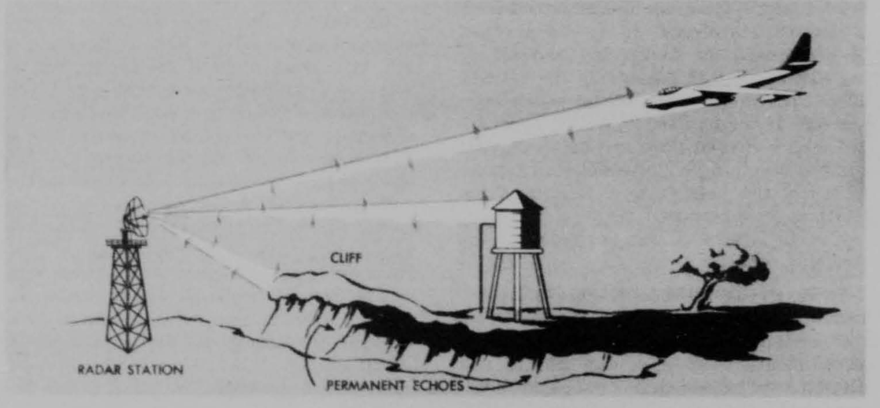

Figure 4-3 Transmission and Reflection of Radar Pulses

Restricted

junction with ionospheric and tropospheric propogation.

Radio waves of extremely high frequency travel in a straight line and with the speed of light. Accordingly, there will be an extremely short time interval between the transmission of the pulse and the reception of the echo. Therefore, it must be possible to measure this very small time interval if the range of the object is to be determined. The cathode-ray tube makes it possible to measure this small time interval with a high degree of accuracy, even to one ten-millionth of a second. (The functioning of the cathode-ray tube will be discussed in detail elsewhere in this chapter).

Radar employs a highly directional antenna to transmit and receive the radio energy in a more or less sharply defined beam. The beam is similar to that of the anti-aircraft searchlight. Therefore, when a signal is picked up, the antenna can be rotated until the received signal is maximum, and the direction of the object may be determined by the antenna position.

4. RADAR METHODS

Continuous-wave

One of the methods for detecting aircraft employs a continuous-wave type of transmission and makes use of the Doppler effect to detect the presence of an object in the space that is being scanned. When radio-frequency energy, which is being transmitted continuously, strikes an object which is moving toward or away from the transmitter, energy is reflected but its frequency is changed slightly. The change in frequency is known as the Doppler effect. A similar effect at audible frequencies is readily recognized when the pitch of a train whistle changes as it approaches and recedes from the listener. The radar application of this effect measures the difference in the frequency between the transmitted and reflected energy to determine the presence and speed of a moving target. This method works well with fast moving objects, but not with slow moving objects since there is very little change in the frequency in the latter case. CW systems are, therefore, limited to the detection of fast moving objects. The rate at which the wavelength will change may be readily computed from the following formula:

$$\Delta\lambda = \lambda \frac{\mu}{v}$$

$\Delta\lambda$ = change in wavelength
λ = wavelength of the transmitted wave
μ = velocity of the object radially from the transmitter.
v = velocity of radio waves.

If the object is moving away from the source of radio energy, the wavelength will be longer, and, therefore, the reflected signal frequency will be lower than the frequency at the transmitter. When the object is moving toward the source of radio energy, the reflected frequency will be higher than that of the transmitter.

Frequency Modulation

A second method that has been employed for radar work is the frequency modulation method. If the frequency of the transmitted energy is varied continuously and periodically over a specified band, the frequency of the energy of the transmitter being radiated at any instant will be different from that being received by the object in space. This difference occurs because of the time required for the energy to reach the object and return. The frequency difference depends on the distance traveled and can be used as a measure of range. Moving objects produce a frequency shift in the returned signal because of the Doppler effect and influence the accuracy of range measurement.

Pulse Modulation

The method most widely employed in modern radar is the pulse-modulation method. Radio-frequency energy can be transmitted in short pulses of a time duration varying from one to fifty microseconds. If the transmitter is turned off before the reflected signal returns from the object in space, the receiver can distinguish between the transmitted and received signals. After all the reflections of interest have returned, the transmitter is again turned on and the cycle is repeated. The receiver collects the returned signal, applying it to an indicator which is capable of measuring the time interval between the transmitted signal and the returned signal.

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Since the velocity of radio energy is constant, the time measurement becomes a measure of the distance traveled and normally is calibrated directly in miles. This method does not depend on the relative frequency of the returned signal or on the motion of the target; thus, the difficulties experienced in the C-W and FM methods are not present.

Determination of Range. The velocity of radio frequency is the same as that of light, approximately 186,296 miles per second, or approximately 328 yards per microsecond.

The constant velocity of radio-frequency energy is applied in pulse-modulated systems to determine range by measuring the time required to travel to the object and return. For example, assume that a pulse, one microsecond long, is transmitted toward an object which is 32,800 yards distant. Figure 4-4 shows the conditions at the instant the pulse is radiated. When the pulse reaches the object, it has traveled a distance of 32,800 yards at 328 yards per microsecond, and therefore, 100 microseconds have elapsed. Figure 4-5 shows the radar pulse just as it arrives at the target. A portion of the pulse is then reflected, and the energy is returned over the same path. Since the return trip is also is 32,800 yards, the time required is again 100 microseconds. Figure 4-6 shows the pulse returned to the radar station. The total elapsed time is now 200 microseconds, since the distance traveled is twice the actual range of the object. For radar ranging, therefore, the velocity is considered to be one half of the true value, or, 164 yards per microsecond. In the example, range = time in microseconds times 164 = 32,800 yards.

In order to employ the time-range relationship, the radar system must have a time-measuring device. In addition, since there may be more than one object in the region under search, some means of separating and identifying pulses must be included. The cathode-ray tube is well suited to such a task since it retains the information on its screen for a short time and also forms a time scale. The time scale is provided by using a linear sweep to produce a known rate of motion of the electron beam across the screen of the cathode-ray tube.

The measurement of time is illustrated in the following example. Assume that a cathode-ray tube is used with a horizontal linear sweep which produces a beam with a velocity of 1 inch per 100 microseconds across the screen. The signals received from an object at a range of 32,800 yards are applied to the cathode-ray tube as a vertical deflection. Following the same sequence of operations as in the previous illustration, Figure 4-7 shows the radio-frequency pulse leaving the radar antenna and the sweep just starting across the screen. In 1 microsecond the leading edge of the pulse has moved 328 yards from the antenna and the sweep trace has moved 0.01 inch across the screen. The pulse is shown on the screen as a vertical deflection since the receiver detects the pulse which is supplied to the transmitting antenna. After 100 microseconds elapsed time, the pulse reaches the object 32,800 yards away, and the sweep trace has moved 1 inch. (Figure 4-8). Since the radio-frequency pulse energy is out at the object, there is no vertical deflection of the trace. The reflected pulse returns to the radar antenna at the end of 200 microseconds, during which time the sweep trace has moved a total distance of two inches. For the length of the received pulse (1 microsecond), the sweep is deflected vertically (Figure 4-9) giving a total elapsed time of 201 microseconds. Thus, with a constant sweep-trace velocity of one inch per 100 microseconds, a time scale is produced which is equivalent to 100 microseconds times 164 yards per microsecond or 16,400 yards per inch of trace. If another object returned the transmitted pulse in 300 microseconds, the returned signal would be indicated 3 inches from the start of the sweep, and the range of the object would be 300 x 164 = 49,200 yards.

The single trace will not persist on the screen of the cathode-ray tube for sufficient time to be useful. Therefore, it is necessary to repeat the pulse transmission and the sweep trace periodically. If the two operations are made to start in the same time relation to each other, signals returned from a given object will be superimposed on each by successive sweeps. The signals from all objects will be shown on the cathode-ray tube in their proper range positions.

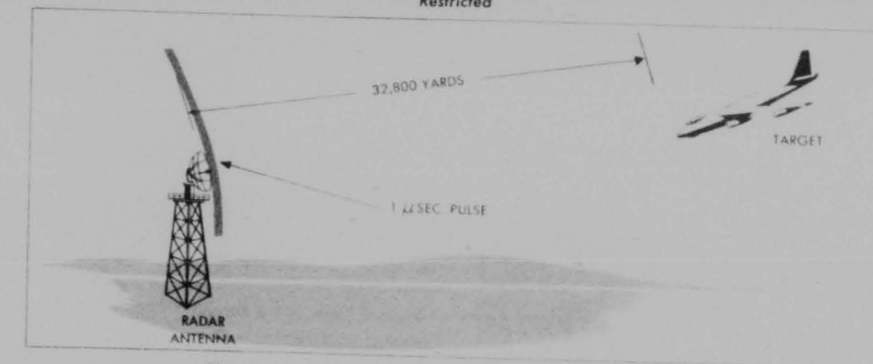

Figure 4-4 Pulse Starts from Antenna: Elapsed Time = 0

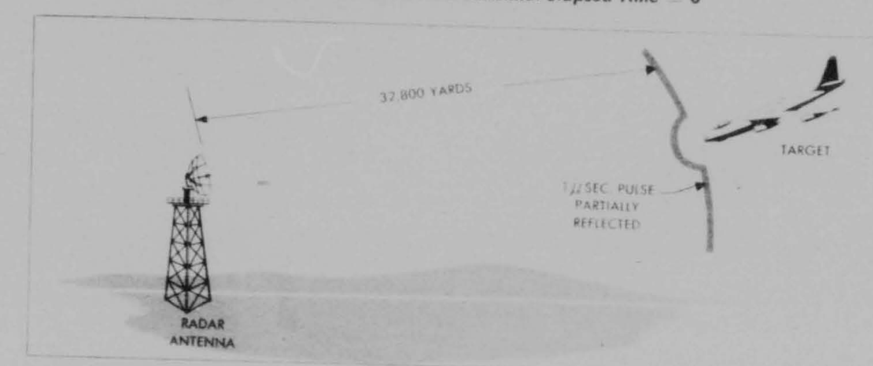

Figure 4-5 Pulse Reaches Target: Elapsed Time = 100 µ Seconds

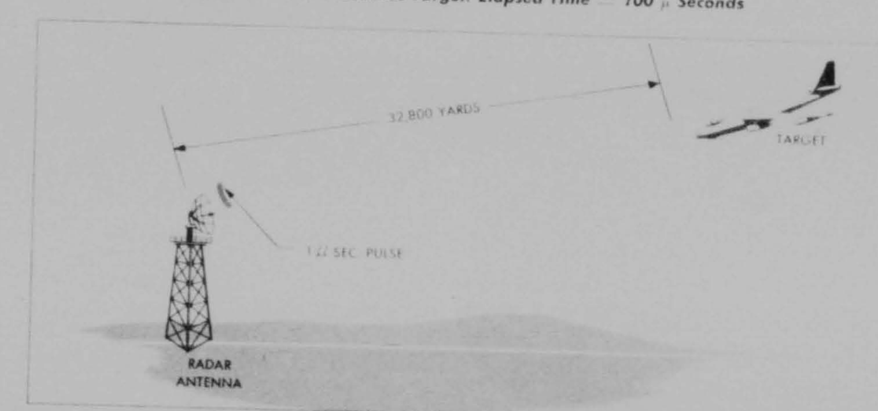

Figure 4-6 Pulse Returns to Receiver: Elapsed Time = 200 µ Seconds

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Figure 4-7 Pulse Leaves Antenna: Elapsed Time = 1 µ Second

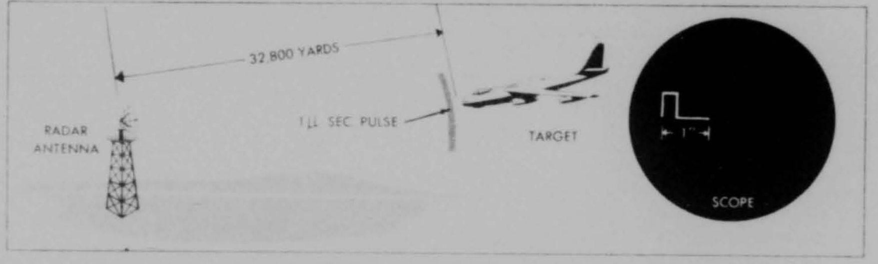

Figure 4-8 Pulse Reaches Target: Elapsed Time = 100 µ Seconds

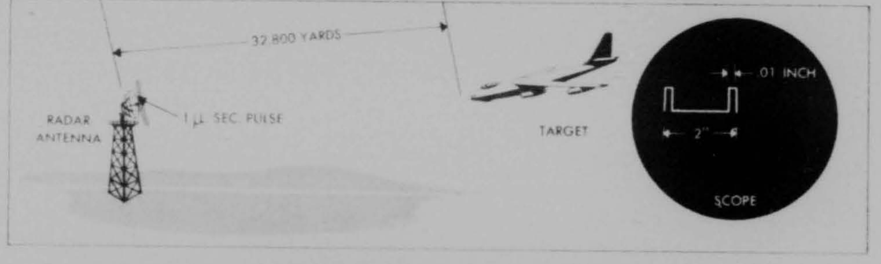

Figure 4-9 Pulse Completes Return to Radar: Elapsed Time = 201 µ Seconds

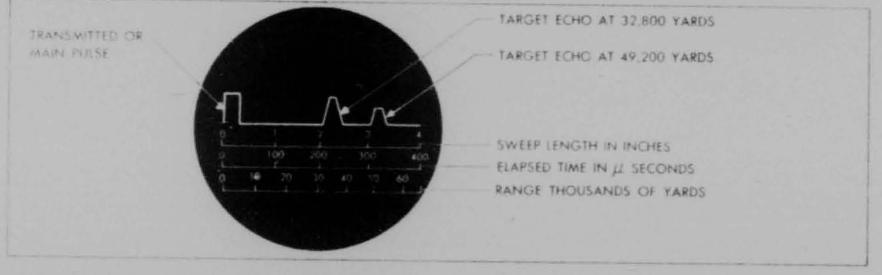

Figure 4-10 Range Indication of Several Targets (Sweep Trace Velocity is 1 Inch Per 100 µ Seconds.

5. PULSES AND DUTY CYCLE

Pulse Repetition Frequency (PRF)

Sufficient time must be allowed between the transmitted pulses for an echo to return from any target located within the maximum workable range of the system. Otherwise, the reception of echoes from more distant targets will be obscured by succeeding transmitted pulses. This necessary time interval fixes the highest frequency which can be used for pulse repetition.

When the antenna is rotated at a constant speed, the beam of energy strikes a target for a relatively short time. During this time, a sufficient number of pulses of energy must be transmitted in order to return a signal which will produce a lasting indication on the face of the cathode-ray tube. The persistence of the screen and the rotational speed of the antenna therefore determine the lowest repetition rate that may be employed.

In a system in which the entire interval between transmitted pulses is used in the indicator, the repetition frequency must be very stable if accurate range measurements are to be made. Since the persistence of the cathode-ray tube will normally be fairly long, successive traces should appear in exactly the same position to avoid blurring.

High-repetition frequencies are employed in radars that are designed for short ranges. Low-repetition frequencies are used in long range radars.

Pulse Length

The minimum range at which a target can be detected is determined largely by the length of the transmitted pulse. If a target is so near the transmitter that the echo is returned to the receiver before the transmitter is turned off, the reception of the echo obviously will be masked by the transmitted pulse.

Normally, it is said that a radar set measures the distance to the target. Actually it measures the time required for a radar pulse to reach the target and be reflected back to the station. Thus, the range scale on a radar indicator is a scale of elapsed time repeated in synchronization with the transmitted pulses. It may be regarded as a distance scale since there is a fixed relationship between a particular distance and the time required for a radar pulse to traverse it in both directions. The minimum range difference at which two targets can be resolved varies directly with the pulse length. With a 1 microsecond pulse, aircraft inseparable in azimuth can be resolved if they differ in range by more than 164 yards plus a small distance which depends on the characteristics of the receiver and indicator. With a 5 microsecond pulse, this limit becomes 820 yards plus the additive constant. In other words, targets may be resolved in range if they are separated by a distance equal to one-half of the pulse length. Since a reflecting object of the smallest possible depth in range will just return the entire pulse, it is apparent that the return from a thin sheet of metal at right angles to the radar beam will have an indicated depth equal to one-half of the pulse length. In a like manner, the indication from objects having considerable depth will be increased by an amount equal to one-half of the pulse length. Obviously, it is desirable that pulse length be as short as possible in order that the best range resolution be obtained.

It is customary to calibrate radar equipment so that range is measured to the beginning of the pulse representing the nearest edge of the target. This removes the range error, caused by the pulse length, on the side of the target nearest the radar but adds the entire error to the far side. Thus, the range accuracy to the near side is unimpaired but, depending upon the shape of the target, identifying characteristics such as size may be obscured. Also, since this is an error in range only, two targets less than one-half pulse length apart will appear on the indicator as a single target.

The major portion of the range error is due to the pulse length, however, a small part of this error is the result of the recovery time of the receiver. The receiver requires a small amount of time to recover from the transmitted pulse before it is in condition to receive a returned pulse.

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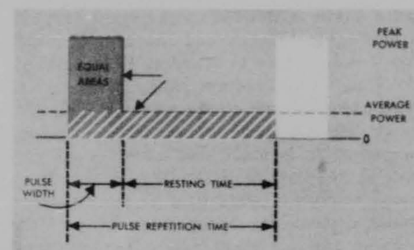

Figure 4-11 Relationship of Peak and Average Power

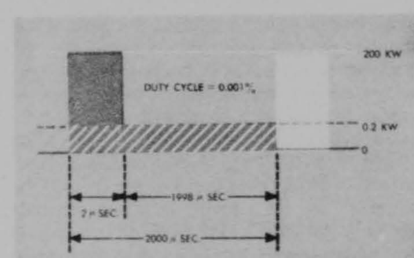

Figure 4-12 Duty Cycle

Average and Peak Power

A radar transmitter generates radio frequency energy in the form of extremely short pulses and then is turned off between pulses for comparatively long intervals. The useful power of the transmitter is that contained in the radiated pulses and is termed the "peak power" of the system.

Power is normally measured as an average value over a relatively long period of time. Since the radar transmitter is resting for a time which is long compared to its operating time, the average power delivered is low when compared with the peak power available during the pulse.

A definite relationship exists between the average power dissipated over the period of one cycle and the peak power developed during the pulse. The time of one cycle of operation is the reciprocal of the repetition frequency, $T = 1/f$. Other factors remaining constant, the longer the pulse length the higher the average power; and the lower the pulse repetition frequency the lower the average power. Thus:

$$\frac{\text{Average power}}{\text{Peak power}} = \frac{\text{pulse length}}{1/f}$$

These general relationships are shown in Figure 4-11.

The operating cycle of the radar transmitter may be described in terms of the fraction of the total time that the RF energy is radiated. This time relationship is called the "duty cycle" and may be presented as:

$$\frac{\text{Pulse Length}}{1/f} = \text{duty cycle}$$

For example, a radar with a pulse length of 2 microseconds and a pulse-repetition frequency of 500 cycles per second will have a duty cycle of 0.001. The time for 1 cycle is 1/500 seconds or 2,000 microseconds and the duty cycle equals 2/2,000 or 0.001.

Likewise, the ratio between the average power and the peak power may be expressed in terms of the duty cycle:

$$\frac{\text{Average power}}{\text{Peak power}} = \text{duty cycle}$$

In the above example, it is assumed that the peak power is 200 kilowatts. For 2 microseconds, then, 200 kilowatts of power are available, while for the remaining 1,998 microseconds, zero power is available. Then: average power $= 200 \times 0.001$ or .2 kilowatts.

High peak power is desirable to produce a strong echo over the maximum range of the equipment. Low average power enables the transmitter tubes and circuit components to be made smaller and more compact. Thus, it is advantageous to have a low-duty cycle. The peak power which can be developed is dependent upon the interrelation between peak power and average power, pulse length, and pulse-repetition frequency.

SECTION 3 - FUNCTIONAL COMPONENTS OF THE RADAR SYSTEM

1. GENERAL

Radar systems, although very much alike in theory, vary greatly in detail. They may be very simple in design and detail or they may be very complicated if the information desired is very extensive. However, a single basic radar system can be visualized in which the functional parts hold equally well for all specific equipment. The varying details are the result of manufacturers' designs and patents, and the degree of refinement of the circuits increases with an increase in frequency.

2. FUNCTIONAL BLOCK DIAGRAM

The functional breakdown of a pulse-modulated radar system resolves itself into six essential components. Figure 4-13 illustrates the block diagram of a pulse-modulated radar system. The functions of the parts may be summarized briefly as follows:

Timer

The timer (also known as the "synchronizer," "keyer," or "control central") supplies the synchronizing signals which times the transmitted pulses and the indicator,

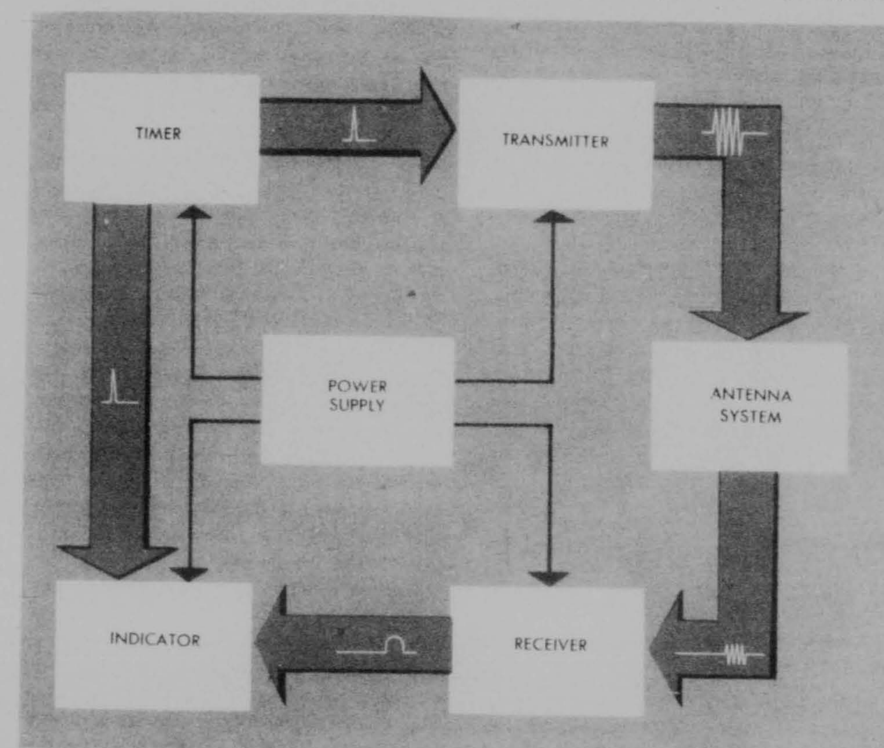

Figure 4-13 Functional Block Diagram of a Fundamental Radar System

and coordinates the functions of other associated circuits. It functions to insure that all circuits connected within the radar equipment operate in a definite relationship with each other and that the interval between pulses is of the proper length. There are two practical methods of supplying the timing requirements.

The first of these methods is the timing by a separate unit. The pulse-repetition frequency, that is, the number of pulses per second, can be determined by an oscillator of any stable type such as a sine-wave oscillator, a multivibrator, or a blocking oscillator. The output is then applied to the necessary pulse-shaping circuits to produce the required timing pulse. Figure 4-14 shows several typical combinations that may be employed for this purpose. The timing of associated components can be accomplished with the output of the timer or by obtaining a timing signal from the transmitter as it is turned on.

Timing also may be accomplished within the transmitter. The transmitter with its associated circuits may establish its own pulse length and pulse-repetition frequency and provide the synchronizing pulse for other components of the system. This action may be accomplished by a self-pulsing or blocking radio-frequency oscillator with properly chosen circuit constants. This method of timing eliminates a number of special timing circuits, but the pulse length and pulse-repetition frequency may be less rigidly controlled than may be desired for some applications.

Transmitter

The transmitter generates the radio-frequency energy in the form of extremely high-powered pulses of very short time duration.

In the self-pulsing radar transmitter, the functions of transmitting and timing are carried out by the same component, as shown in Figure 4-15. This type of transmitter in effect oscillates at two frequencies; the carrier frequency, as determined by the LC constants of the tank circuit, and the pulsing frequency as determined by the RC constants of the grid circuit. The grid capacitor largely controls the pulse length in that its size determines the number of positive RF swings required to charge it sufficiently to block the transmitting tube. The grid leak resistor controls the pulse repetition frequency to the extent that it determines the time required for a sufficient charge to leak off the grid capacitor to unblock the transmitting tube. The timing pulse for other components is developed across a resistor in the cathode circuit of the blocking oscillator.

In the externally pulsed type of radar transmitter, the function of the radio frequency is relatively simple. It generates powerful impulses of radio frequency energy at regular intervals. As the resting time is very long compared with operation time, the oscillator may be greatly overloaded and thus the peak power output may be increased. In this type of operation, the transmitter requires power in the form of high-amplitude square-topped waves that are properly timed. In most cases, the oscillator cannot perform its function directly and therefore it is necessary to use a driver and modulator (Figure 4-16). A driver in any circuit, when triggered, drives the modulator with a rectangular pulse of accurately timed length. A modulator is a circuit which supplies power to the radio-frequency oscillator in the form of a timed, high-amplitude, rectangular pulse. The driver, when triggered, shapes a rectangular pulse of proper time length which in turn operates the modulator. The modulator then furnishes the high-plate voltage to the radio-frequency oscillator for the predetermined pulsing time. Thus the transmitting function may be carried out by the combined performance of a driver, modulator, and the radio-frequency oscillator. The modulator acts as a power amplifier for the driver and as a switch for the radio-frequency oscillator.

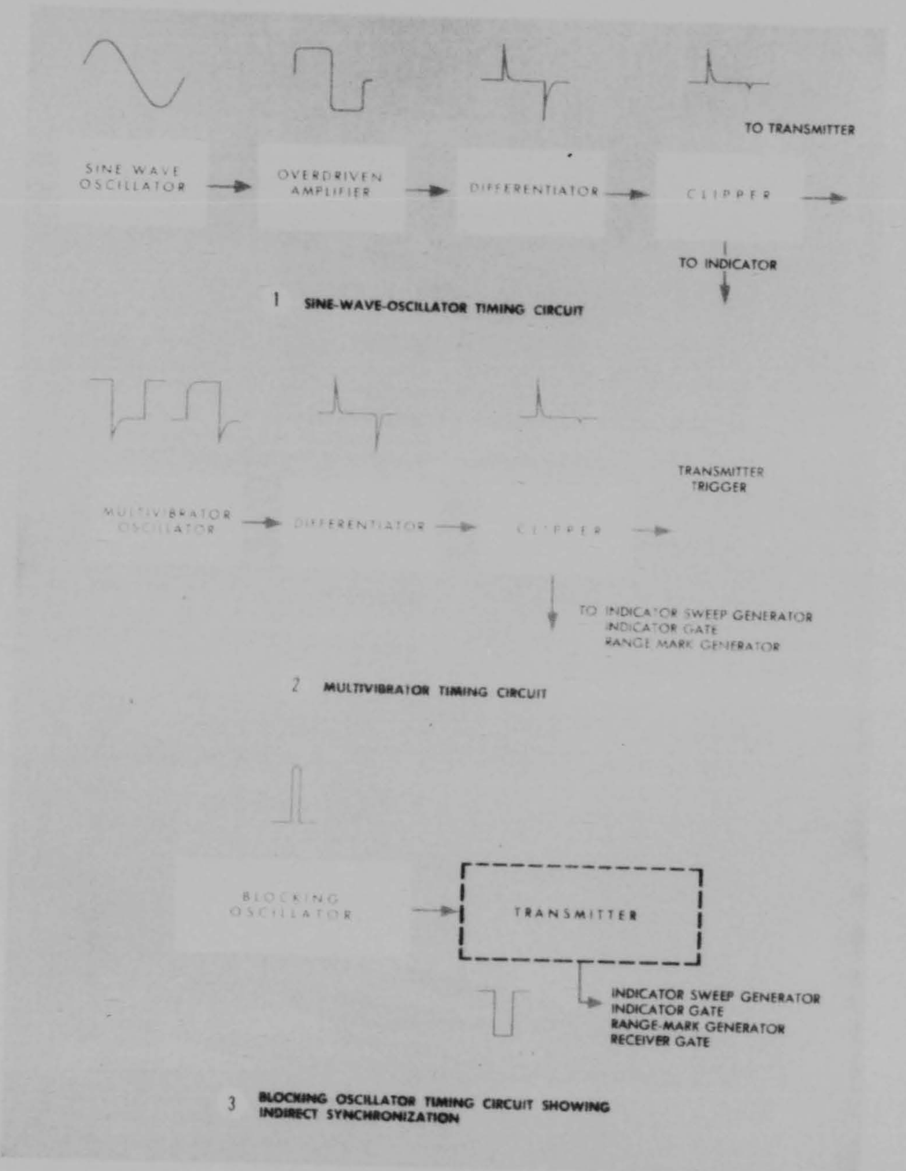

Figure 4-14 Representative Methods of Timing Radar Systems

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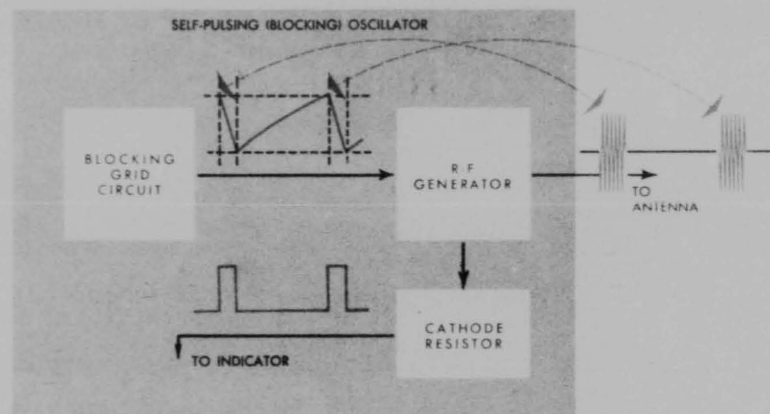
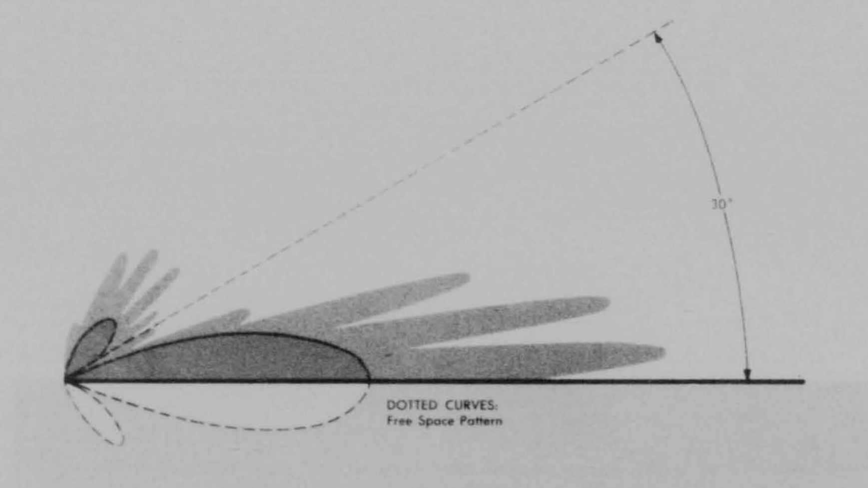


Figure 4-15 Self-Pulsing Oscillator Functioning as Transmitter and Timer

Antennas

The function of the antenna system is to take the energy from the transmitter, carry it to a radiating element, reflect it into a narrow directional beam, recover a portion of the returned energy and pass it to the receiver with a minimum of loss. The antenna system consists of the radio-frequency transmission lines from the transmitter to the radiating antenna array, the antenna array itself, and the transmission line from the antenna array to the receiver. Any antenna switching device or receiver protecting device is considered part of the antenna system.



Simple Antenna Pattern Showing Ground Reflection

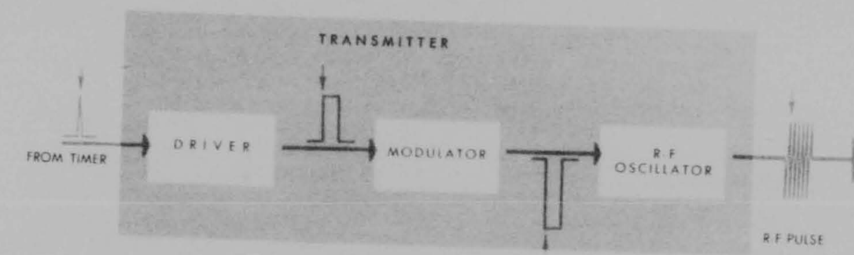


Figure 4-16 Externally-Pulsed Transmitter

Whenever a receiver is operated in close proximity to a transmitter, a certain amount of energy inevitably finds its way into the receiver directly from the transmitter by means of stray capacitance of the input circuit leads. In certain instances, such signals resulting from the main transmitted pulse must be eliminated entirely from the output of the receiver. Therefore, the receiver input circuit must be gated, or turned off during the time of transmission so that it will be completely insensitive to any transmitted signal.

Sometimes, it is desirable to couple a small amount of the transmitted radio-frequency energy to the receiver for timing purposes. However, the signal directly available from the transmission line is so large that the receiver input circuit may be burned out. Because of the high sensitivity of the receiver, the strong signal also will cause blocking of the receiver tubes which employ RC grid circuits. This blocking occurs because the tubes are overdriven, causing the grids to pass current and charge the capacitors in the grid circuit. After the signal has passed, the charge remains as a grid bias which is much greater than cutoff. Both of these conditions

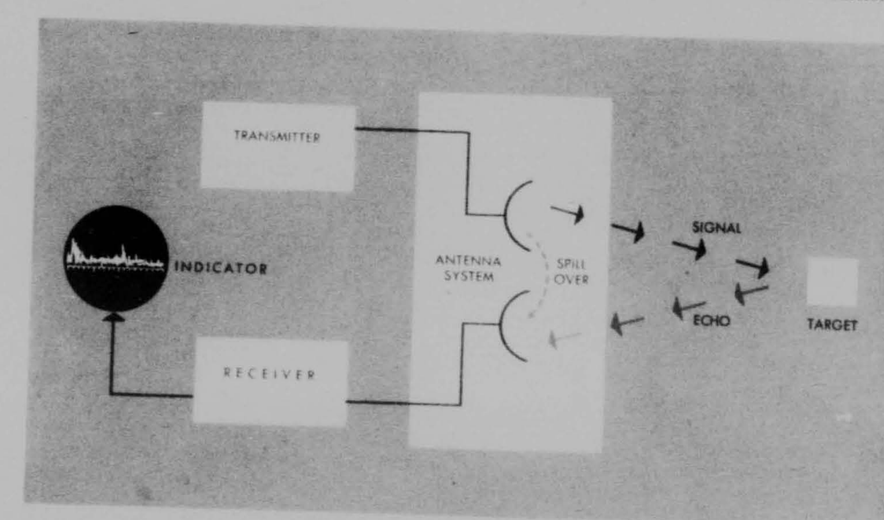


Figure 4-17 Simple Antenna System for Transmitting and Receiving

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place a limit on the amount of transmitted pulse which can be allowed to reach the receiver. These are the reasons for employing receiver protective devices. It has been previously mentioned that radar is capable of measuring a minimum range equal to one-half the pulse length plus a small distance which is dependent upon the characteristics of the receiver and the indicator. The time required by the receiver to recover from the transmitter is a portion of the additional distance. The amount of time required for the receiver to recover is partly dependent upon the efficiency of the receiver protective device.

The simplest antenna system contains two antenna arrays; one for transmitting and one for receiving (Figure 4-17). In this arrangement, the receiving antenna must be shielded from the powerful pulses of energy that are transmitted. Usually, the directivity of the antenna system is sufficiently great to permit the location of the receiving antenna in a region of minimum radiation. In an aircraft, the fuselage may be used for a shield.

A more practical method of solving the problem is the use of a single antenna and a switch capable of connecting the antenna to the transmitter or the receiver at the proper instant. The switch protects the receiver during the time the pulse is being transmitted and isolates the transmitter from the receiving circuit during the time of reception. Otherwise, the weak signals returned would be lost or partially lost in following the transmission line back to the transmitter. It is nearly impossible to devise a mechanical switch capable of performing the job efficiently. Most of the switches for this task are of the electronic type, and are called "T-R" (transmit-receive) boxes.

The system for using a single antenna must be as efficient as possible. All of the energy generated by the transmitter should be radiated from the antenna. All the returned energy should reach the receiver. This efficiency is most easily obtained by matching the impedance of the antenna to the characteristic impedance of the transmission line. During the transmission of the pulse, the transmitter must be matched to the transmission line and the receiver must present an open circuit of high impedance to the transmission line. During the reception time the conditions must be reversed. Figure 4-18 illustrates the employment of a mechanical switch.

The problem of switching is simplified because most transmitters have a different impedance when they are operating than when they are inoperative. If properly matched during the pulse transmission time, the transmitter will be mismatched during the receiver time and the transmission line will become resonant. A typical antenna system in which the receiver and the transmitter are connected by branch line to the antenna is illustrated in Figure 4-19. The junction of the three lines is known as a T-junction.

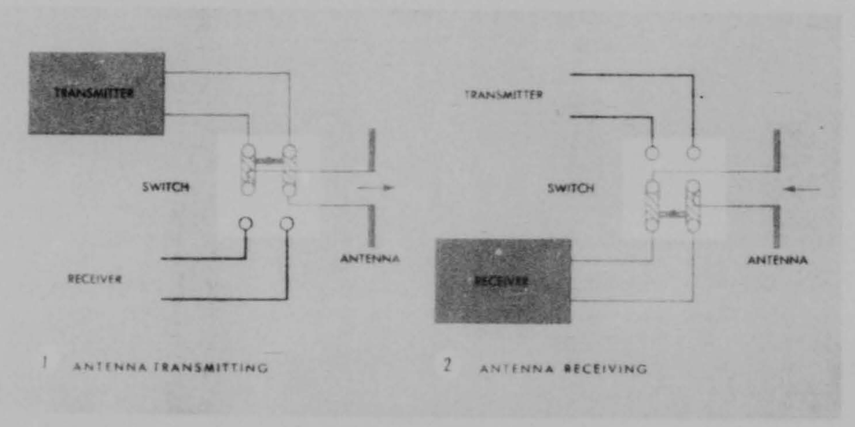

Figure 4-18 Mechanical Antenna Switch

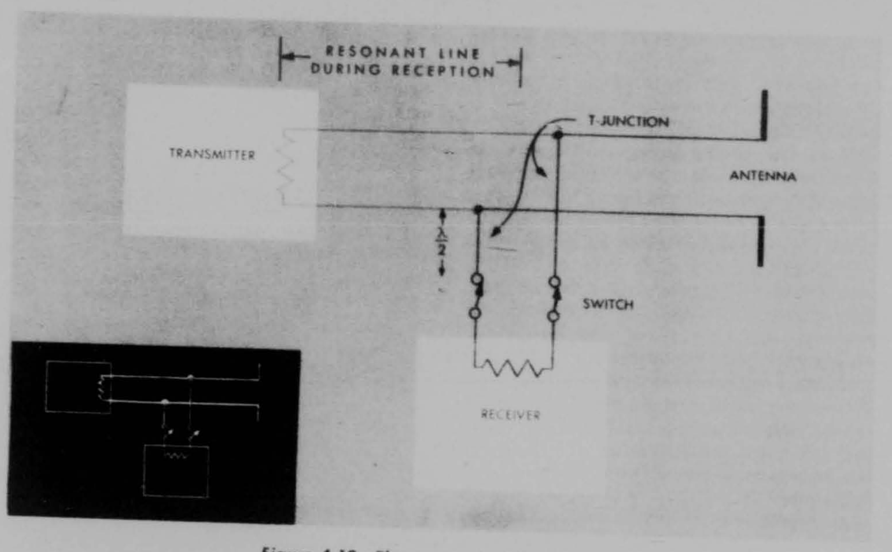

Figure 4-19 Elementary Switching System

Figure 4-20 illustrates one of the types of electronic transmit-receive switches. The spark gap used in a given T-R system may vary from a simple one formed by two electrodes placed across the transmission line to one enclosed in an evacuated glass tube with special features to improve operation. The requirements of the spark gap are that its resistance be very high until the arc is formed, and then very low during conduction through the arc. At the end of the transmitted pulse, the arc should be extinguished as rapidly as possible to remove the loss caused by the arc, and to permit signals from nearby targets to reach the receiver.

The simple gap formed in air has a resistance of from thirty to fifty ohms. This is usually too high for use with any but an open-wire transmission line. The time required for the air surrounding the gap to be completely deionized after the pulse voltage has been removed is about ten microseconds. During this time the gap acts as an increasing resistance across the transmission line to which it is connected. However,

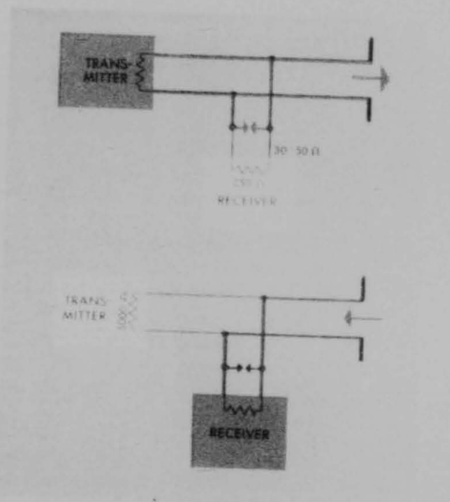

Figure 4-20 Electronic T-R Switch

in a T-R system using an air gap the received signals reaching the receiver through the gap have half their proper magnitude after three microseconds. This is known as recovery time.

The value of the voltage to break down a gap, and the running voltage during the arc may be lowered by reducing the pressure of the gas surrounding the electrodes. T-R tubes are therefore used in which the spark gap is inclosed in a glass envelope and the tube is partially evacuated. The arc is formed by conduction through an ionized gas or vapor so that the tube cannot be entirely evacuated; thus there is an optimum pressure which will give the best T-R operation. The recovery time or deionization of the gap can be reduced by introducing water vapor into the tube rather than air. A T-R tube containing water vapor at a pressure of 1 millimeter of mercury will recover in .5 microsecond.

The principal types of **radiators** employed in radar systems are: the stacked dipole array with untuned reflector, the dipole with tuned reflector and directors, the dipole with parabolic reflector, and various arrangements of dielectric radiators used in conjunction with wave guides.

The type of antenna which is widely used in radar equipment is the dipole with a parabolic reflector. Since microwaves have characteristics very similar to those of light waves, the parabolic reflector is very efficient at microwave frequencies. If the dipole is placed at the focal point of the reflector, the energy will be concentrated into a beam in much the same manner as a search-light reflector controls a light beam. The parabola converts the spherical waves as radiated by the dipole into a plane wave after reflection. The parabolic reflector may take many forms. Figure 4-21 illustrates the principle of the parabolic antenna.

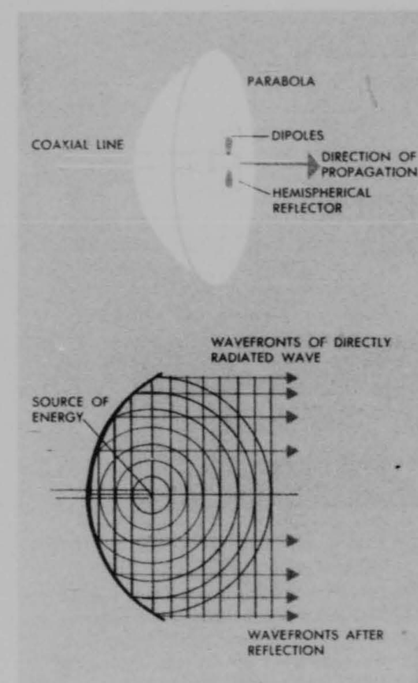

Figure 4-21 Parabolic Antenna

Receivers

The function of the receiver is to amplify the weak signal that is returned by the target to the antenna system, and feed the pulses to the indicator. Since the radar frequencies are high, it is difficult to obtain sufficient amplification. The radar receiver is usually of the superheterodyne type with good stability and extreme sensitivity. The stability is maintained in the microwave region by careful design and the over-all sensitivity is greatly increased by the use of many stages of the intermediate frequency amplification with each stage having a rather low amplification factor. Special types of tubes having low interelectrode capacitance have been developed for use in the radio frequency and intermediate frequency stages.

Figure 4-22 illustrates the block diagram of a typical radar receiver. The radio frequency amplifier may not be present in the higher frequency ranges and thus the received signal may be fed directly to the mixer stage. In this case, it is desirable to use as short a receiver input transmission line as design requirements permit. The mixer and local oscillator may be close to the T-junction of the transmission line in

order that the received radio frequency may be converted to the lower intermediate frequency before being relayed to the remaining stages of the receiver. One or two stages of intermediate frequency amplification are frequently located immediately after the mixer stage and function as a preamplifier to offset the considerable attenuation encountered in coupling the weak signals to the components of the receiver which may be located at some distance from the antenna system. The radio frequency components of the receiver are normally located near the antenna in order to reduce the problem of transmitting this radio frequency any distance since there is a considerable engineering problem in transmitting radio frequency over transmission lines.

Indicators

For many years, the study of high-frequency phenomena was impeded by the lack of an oscillograph which would respond to very rapid changes in current and voltage. Mechanical oscillographs are incapable of following changes occurring at rates faster than a few thousand cycles per second.

The electron is nearly instantaneous in its response to the influence of electric and magnetic fields. The development of the vacuum tube suggested its use as an electronic device in the study of high-frequency phenomena.

In order to determine the range, azimuth, and height of a target, the indicator uses the received signal to produce a visual indication of the desired information. The cathode-ray tube, which is a type of vacuum tube, is an ideal instrument for the presentation of radar data since it not only shows a variation of a single quantity, such as a voltage, but gives an indication of the relative values of two or more synchronized variations. The usual indicator is basically the same in function as the low-frequency test oscilloscope that is employed so extensively in the laboratory. The focusing, intensity, and positioning controls are similar. The sweep frequency of the radar indicator is determined by the pulse repetition frequency of the radar system and the sweep duration is established by the setting of the range-selector switch.

The Cathode-ray Tube. The simpler systems of data presentation generally employ electrostatic deflection of the cathode-ray tube. The electron beam is made to follow some pattern by means of controlled differences in potential between pairs of deflecting plates.

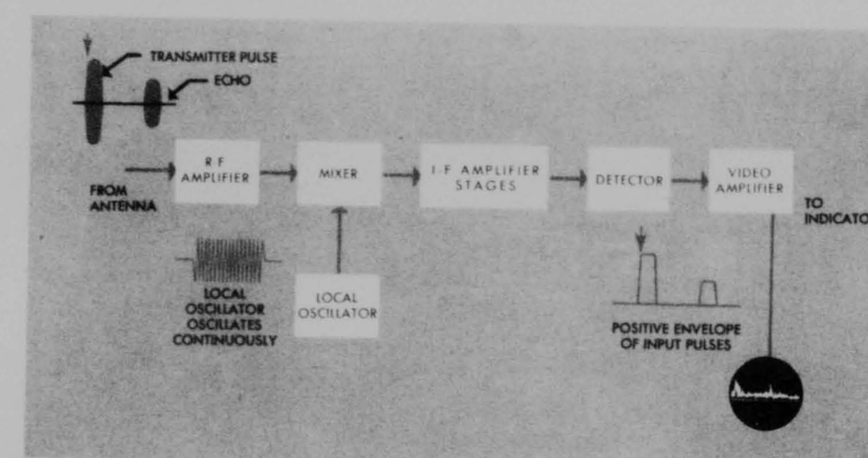

Figure 4-22 Components of Radar Receiver

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The more highly refined systems of data presentation generally utilize the electromagnetic deflection of the cathode-ray tube with a long persistence screen. The position of the electron beam at any instant is determined by causing it to pass through a magnetic field produced by control currents passing through deflecting coils mounted outside the cathode-ray tube. If intensity modulation is used, the bias is such that the tube is held just beyond cutoff and the video output of the receiver is applied to either the grid or the cathode with such polarity as to release the beam of electrons and allow the trace to appear on the screen. Thus, the bright spots on the screen represent returning echoes detected by the radar system.

The basic cathode-ray tube in its present form consists of six principal parts contained within an evacuated tube.

A hot cathode for producing the electrons to form the beam. The cathode is heated by a filament.

A grid is employed to control the number of electrons escaping from the cathode and to control the intensity of the electron beam.

A first anode to draw the electrons from the cathode into the beam.

A second anode is employed to accelerate the electrons and to focus them into the beam so that they will strike the screen in a pinpoint spot.

Electrodes or coils to deflect the electron beam by means of the voltage or current to be observed.

A fluorescent screen which is excited by the electron beam to produce a visual indication of the path followed by the electron beam.

The first four parts of the cathode-ray tube constitute what is commonly known as the "electron gun," since they serve to generate and direct the stream of electrons into a beam which constitutes the moving element of the cathode-ray tube.

Electrostatic Deflection. The elements of a typical cathode-ray tube employing electrostatic deflection are shown in Figure 4-23. The electrons emitted by the cathode are focused and acelerated by the action of the grid and anodes. By virtue of the aperture in the various tube elements and the form of the electric field around the two anodes, the electron beam is constricted into a narrow beam which passes between each of the two sets of deflecting plates before reaching the screen. In this tube, the beam is focused and deflected by electrostatic action. If a voltage is applied to the horizontal deflecting plates and made to vary in some predetermined manner, the electron beam passing between these plates can be made to vary its position in such a manner that it will sweep from one side of the tube to the other. Now, if a voltage is introduced to the vertical deflection plates, the electron beam will be deflected by that voltage also. The position of the electron beam is the result of two voltages applied to the two sets of deflecting plates. If the voltage applied to the vertical deflection plates is taken from the radar receiver, the signal returned by the target in space will cause the electron beam to be deflected upward and produce visual indication of the target.

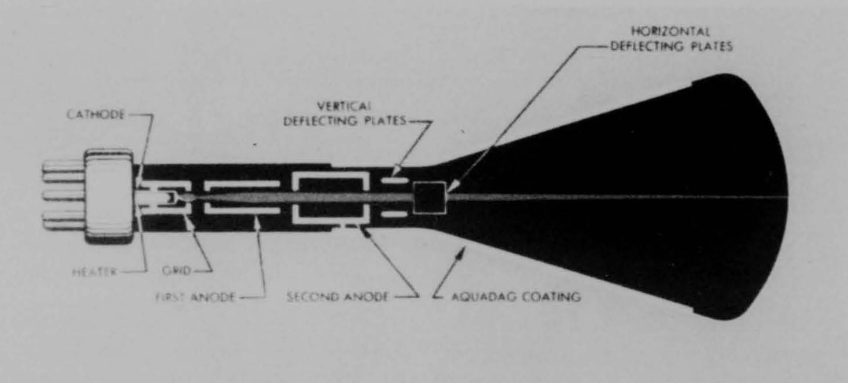

Figure 4-23 Electrostatic Cathode-Ray Tube

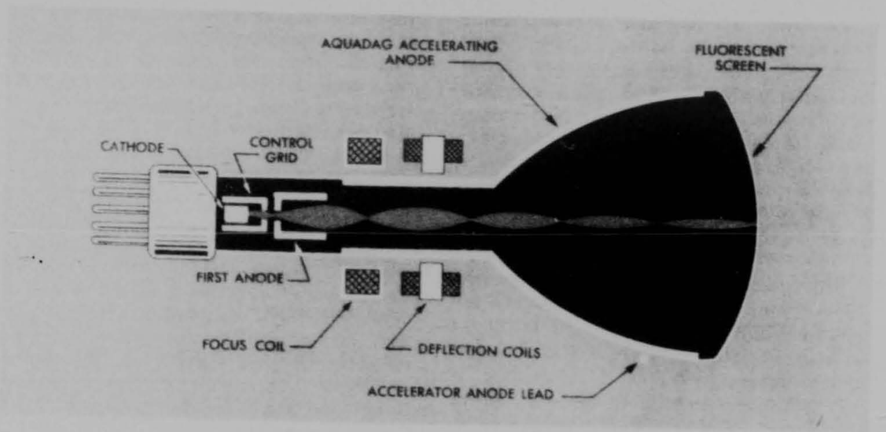

Figure 4-24 Electromagnetic Cathode-Ray Tube

Electromagnetic Deflection. The electromagnetic type of cathode-ray tube has come into common use because of the greater definition possible with magnetic focusing. Also, electromagnetic deflection has a number of advantages over electrostatic deflection, particularly when a rotating radial sweep is required to give polar indications.

The production of the electron beam in the electromagnetic cathode-ray tube is essentially the same as in the electrostatic cathode-ray tube. The grid structure is similar and the use of the grid to control the number of electrons in the beam is identical. The elements of a typical cathode-ray tube employing electromagnetic focusing and deflection are shown in Figure 4-24.

The focusing coil of an electromagnetic tube is wound on an iron core. This core is generally constructed with a small airgap for concentrating the magnetic field. The coil may be moved along the neck of the tube to a limited extent in focusing the beam, but the normal method, after the coil is in the proper position, is to vary the amount of current flowing through the coil.

There may be only one pair of coils employed to produce the desired effect, and in some cases they will be arranged so that they can rotate around the axis of the tube. In other types of usage, two pairs of coils are employed to produce the same results. These will, in general, be fixed or relative to the tube and will be at right angles to each other. Two anodes are used for accelerating the electrons from the cathode to the screen of the tube (Figure 4-24). The second anode is the graphite coating on the inside of the glass envelope. The envelope is shaped differently from that of the electrostatic tube, since it is necessary to have enough space along the neck for both the focusing and the deflection coils. These coils must be mounted as close to the electron beam as is physically possible.

Cathode-ray tubes in which the focus is electrostatic and the deflection is electromagnetic are employed in certain applications. Other special types are those in which the focusing or deflection may be accomplished by electromagnetic action. Such special types of cathode-ray tube are not widely used.

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The relative advantages of electrostatic and electromagnetic control are as follows:

The electromagnetic tubes have a greater structural simplicity (the electromagnetic tube has no deflecting plates or focusing anode that must be carefully aligned); greater ruggedness, which makes for greater reliability in mobile equipment; and shorter tube lengths which reduces the over-all size of the equipment in which electromagnetic cathode-ray tubes are used.

Electrostatic - cathode-ray tubes require little voltage or current to produce the required deflections. Therefore, the auxiliary circuits are simpler and difficulties from deflecting coil inductance are avoided.

Practically all cathode-ray tubes are coated on the inside of the envelope with a graphite coating (Aquadag coating) whose primary function is to attract secondary emissions of the fluorescent screen. If electrons were allowed to pile up on the screen, it would soon require a very large negative voltage to operate the tube. This would interfere with normal operation. When the electron beam strikes the screen, some of the energy of the electrons is given up in dislodging electrons in the fluorescent coating employed in the screen. These dislodged electrons are known as "secondary emissions." If the number of secondary electrons emitted equals the number that originally strike the screen, there will be no change in the fluorescent screen voltage and the tube will continue to function properly. The graphite coating is also used to provide shielding for the electron beam. In some cathode-ray tubes there is no metallic accelerating anode and the graphite coating is connected so as to perform this function as well.

In some types of electrostatic tubes, an extra anode, called an "intensifying ring," is used to increase the brilliancy of the spot on the screen. This ring is made of metal and is cemented to the inside of the glass. It accelerates the electron beam after deflection has taken place and gives the electron beam greater kinetic energy, thus causing the spot to be more brilliant.

Fluorescent Screens. To convert the energy of the electron beam into visible light, the area where the beam strikes is coated with a phosphor chemical which has the property of emitting light when bombarded with electrons. This property is known as "fluorescence." Continued emission of light for a short time after bombardment is called "phosphorescence."

All fluorescent materials are associated with a characteristics relationship between the intensity of the emitted light and the colors contained in that light. Willemite, which emits a green light, has been used generally for coating cathode-ray tube screens. Recently, however, other materials have been developed which emit different colors, and have varying abilities to hold the image on the screen when the electron beam has passed on. Typical phosphors or fluorescent materials used are as follows:

Willemite (zinc othosilicate), for predominantly green light.

Zinc oxide, for predominantly blue light.

Zinc beryllium silicate, for predominantly yellow light.

Zinc sulphide and cadmium zinc sulphide mixture, or zinc beryllium silicate for nearly white light.

All fluorescent materials have some afterglow, or phosophorescence, but the duration of the afterglow varies with the material, as well as with the amount of energy in the beam causing the emission of light. For oscilloscopes that are used for observing nonrepeating phenomena or periodic phenomena which ocur at a low repetition rate, a screen material on which the image will linger is desirable. The screen of such a tube is described as having "long persistence," since the light emitted by phosphorescence fades out slowly. In applications where the image changes rapidly, afterglow is a disadvantage, since it may cause confusion on the screen. Manufacturers generally designate the persistence and color of the screen of cathode-ray tubes.

The intensity of the spot on the screen of a cathode-ray tube is dependent on two factors: first, the speed of the electrons striking the screen; second, within limits, the number of electrons that strike the screen at one point within a certain length of time. The amount of light which the phosphor is capable of emitting is limited and

once the maximum has been reached, further increase in the electron bombardment has no effect on the light intensity. There are obviously two ways of controlling the intensity of the spot in an oscilloscope. One way is to increase the speed of the electrons when it is desired to make the spot brighter, and to decrease this speed to make the spot less intense. Since changing the speed requires that other adjustments be made in the tube, this method is not generally used. The second way of controlling the spot intensity is to control the number of electrons in the electron beams by applying suitable control voltages to the control grid.

The images on the screen of a PPI are produced by fluctuations in the intensity of a moving beam of electrons which sweep across the face of the cathode-ray tube. Since the coating on the inside of the tube has a finite thickness, the final image as it appears on the face of the tube is diffused or spread in all directions. For the cathode-ray tubes now in general use, this diffusion is in the order of 0.01 inch. That is, the minimum distance on the screen between the centers of two spots which just touch each other is approximately 0.02 inch. If nothing else limited the resolution of the PPI, the indicated size of the object would be increased by a fringe equal to 0.01 inch.

It should be understood that this figure is variable within rather wide limits, depending on the position of the target on the screen, the receiver gain and focusing adjustments of the indicator, and the reflecting qualities of the target. It should probably be considered a minimum figure rather than an average figure.

Since the distance from the center of the PPI to the edge of the tube will represent different ranges for different setting of the range selector-switch, the distance represented by the diffusion will also vary. For example, if the PPI is used on the 20-mile scale, the diffusion amounts to 486 feet, while on the 100-mile scale it amounts to 2,430 feet.

Power

In the functional diagram of the radar system, the power supply is represented as a single block. However, it is unlikely that any one power supply would meet the complete requirements of a radar system. Normally, each component requires voltage of several different values in order to make it operative. In addition, some primary source of power must be supplied. Figure 4-25 illustrates a diagram of power supply used in connection with some radar equipment, however, it is not complete.

3. TYPES OF OSCILLOSCOPE PRESENTATION

Figures 4-43 through 4-50 are illustrations of the most common types of radar-scopes in current use. It is not an all-inclusive representation since special adaptations of these basic types may be made for special applications. General information is given in connection with each figure.

SECTION 4 - THE APPLICATION OF RADAR PRINCIPLES

1. GENERAL

Radar is still in a state of development, but it is possible to rely upon the information that radar equipment is able to furnish so that the greatest possible benefits may be obtained through its use. In considering this subject, one must not think in terms of the present but in terms of radar requirements of the future. A radar system may be the only practicable warning device in the event of another war.

2. THE IDEAL RADAR

In this discussion, the radar of the future is referred to as the "ideal radar" and is endowed with six functions which it must have in order to fulfill its mission. The six items of information which radar must furnish are: range; azimuth or bearing; eleva-

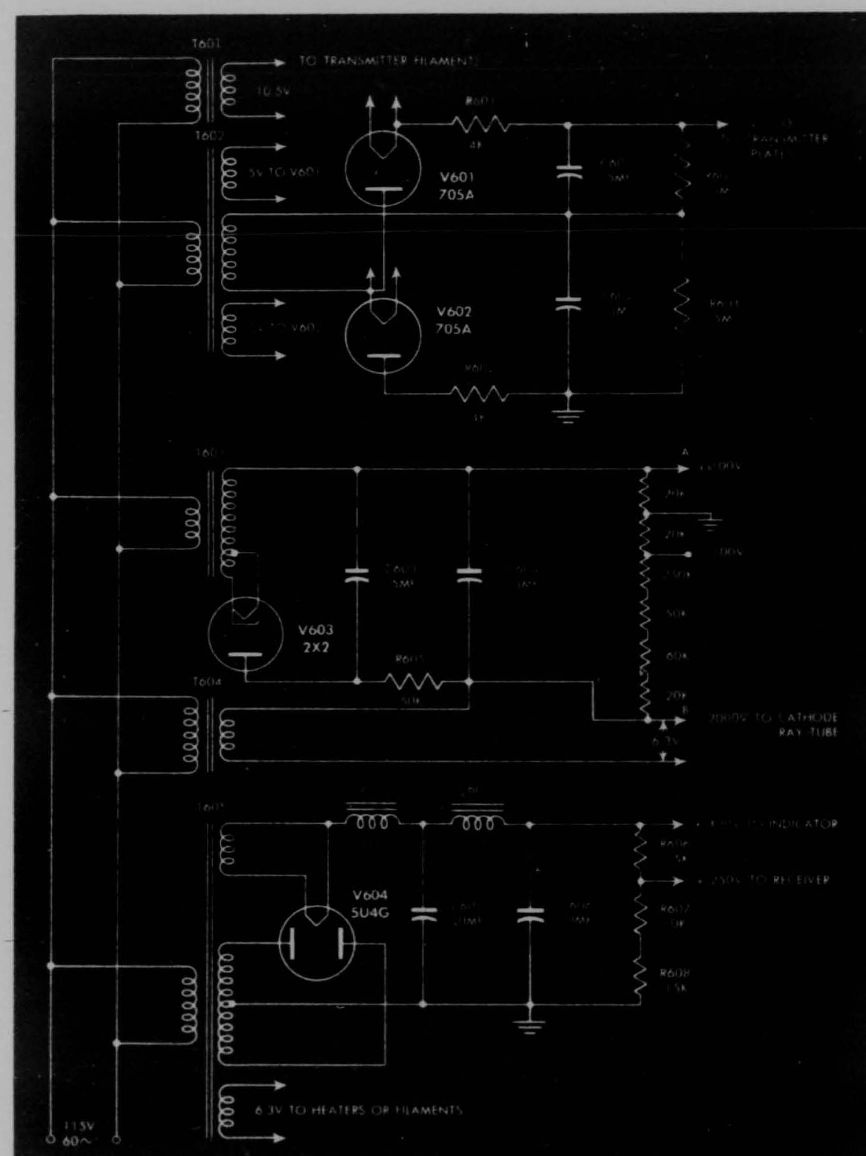

Figure 4-25 Schematic Diagram of Power Supply Circuits

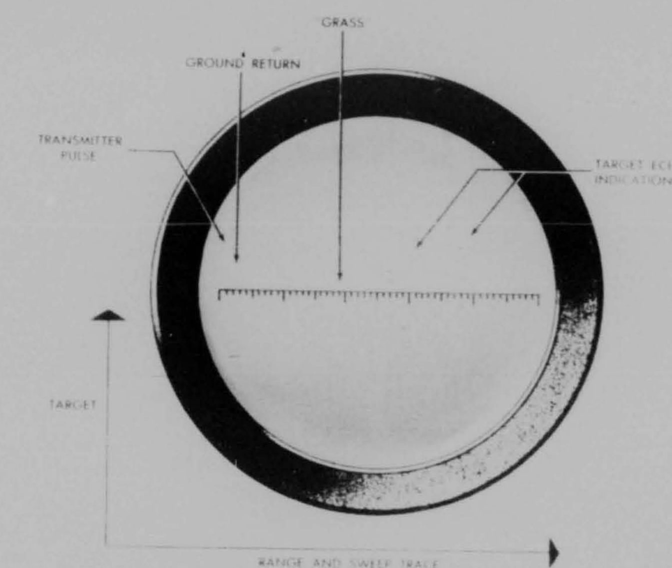

Figure 4-26 A-Type Radar-scope Display

A-Type

Description:	An indicator with a horizontal sweep trace giving range only. Signals appear as vertical deflections above or below the time scale.
Data presented:	Range is read horizontally from left to right. Azimuth is read from a dial on the antenna or from a counter operated by the rotation of the antenna. Elevation data not presented.
Target indication:	Appears as a deflection of the trace at target range. Deflection may be up or down.
Type deflection:	Electrostatic.
Application:	Determining range, test scope, IFF display.

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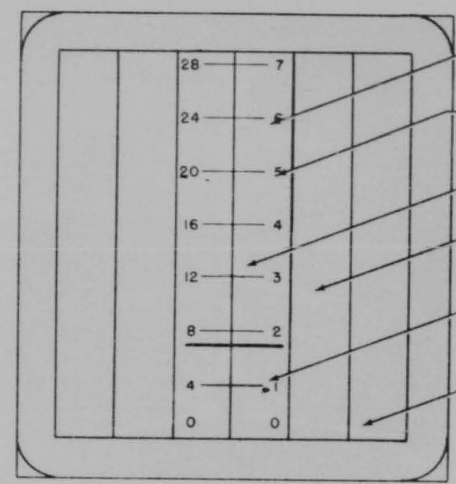

Figure 4-27 Modified A or L-Type Radar-scope Display

Modified A- or L-Type

Description: A modification of A-type for aiming a double lobe system in azimuth. A vertical time base indicates range. The signal from the left lobe appears as a horizontal deflection to the left; the signal from the right lobe appears as a horizontal deflection to the right. The ratio of the signal amplitudes is indicative of the error in homing.

Data presented: Range is presented bottom to top. Azimuth obtained by matching pips and homing on the target. Elevation is not presented.

Target indication: Deflection left from left antenna or lobe, and right from right antenna, or lobe.

Type deflection: Electrostatic.

Application: Determining range and relative bearing.

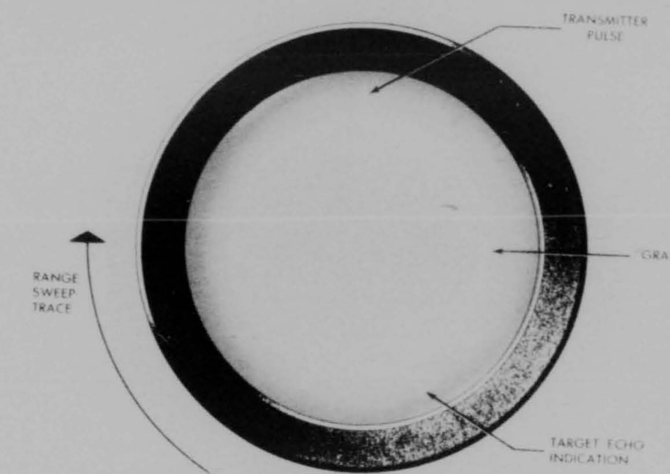

Figure 4-28 J-Type Radar-Scope Display

J-Type

Description: A modification of A-type in which the sweep produces a circular range scale near the circumference of the CRT face. The signal appears as a radial deflection of the time trace.

Data presented: Range is presented on the circumference in a clockwise direction. Azimuth is read from a dial on antenna or geared to antenna at maximum echo as antenna rotates. Height not presented.

Target indication: Deflection from circle.

Type deflection: Electromagnetic.

Application: Gunlaying, radio altimeter, Shoran.

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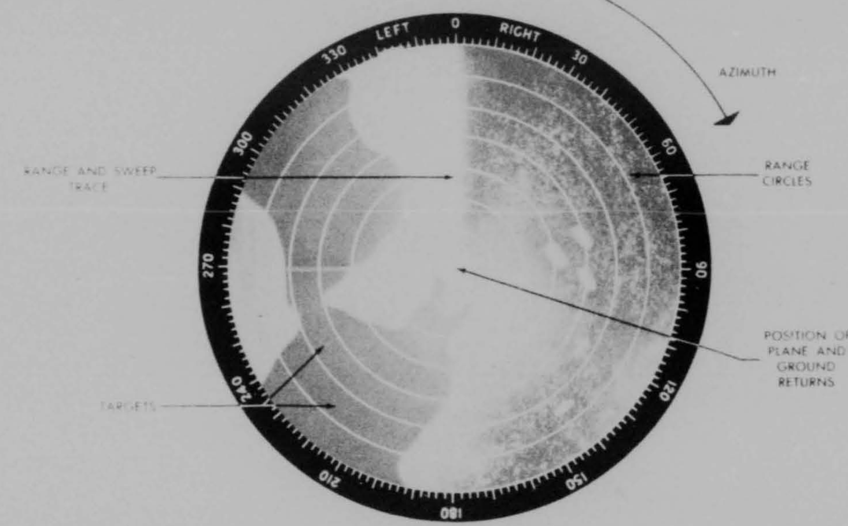

Figure 4-29 PPI-Type Radar-Scope Display

Plan Position Indicator (PPI)

Description: The sweep is a radius of the tube face (from center to edge) and moves through 360°. It gives azimuth by direction of the radial line and range by the distance of the signal from the center of the screen.

Data presented: Range is read radialy from the center of the tube. Electronic range markers may be added. Azimuth is read around the circumference of the tube. Trace rotates with the antenna. No height provision.

Target indication: Target appears as a bright spot on face of tube at correct range and azimuth.

Type deflection: Electromagnetic.

Application: Low-altitude blind bombing, high-altitude blind bombing, surface search, air search, tactical control of aircraft.

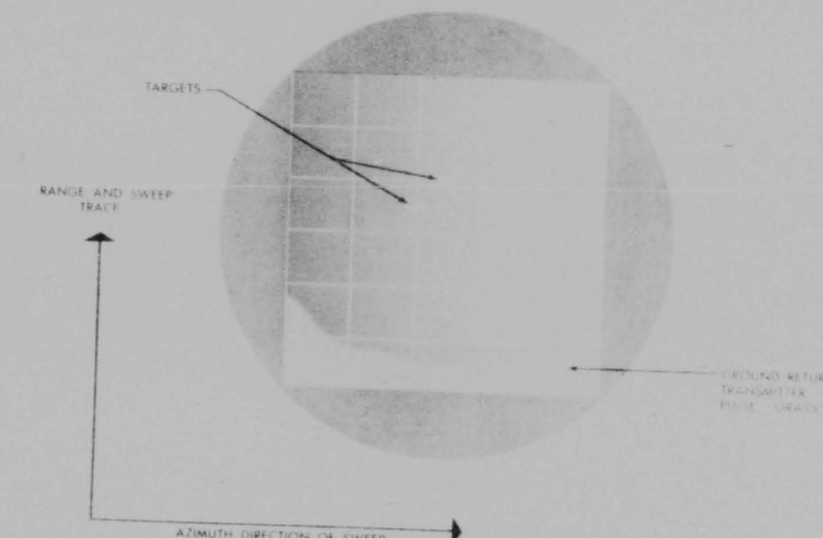

Figure 4-30 B-Type Radar-Scope Display

B-Type

Description: In B-type presentation, the signal appears as a bright spot with azimuth angle as the horizontal coordinate and range as the vertical coordinate.

Data presented: Range is presented vertically bottom to top. Azimuth presented left to right using a fixed number of degrees (sector scan). No height given. Electronic range and azimuth.

Target indication: Bright spot at correct range and azimuth.

Type deflection: Electromagnetic.

Application: Aircraft interception (airborne), air search.

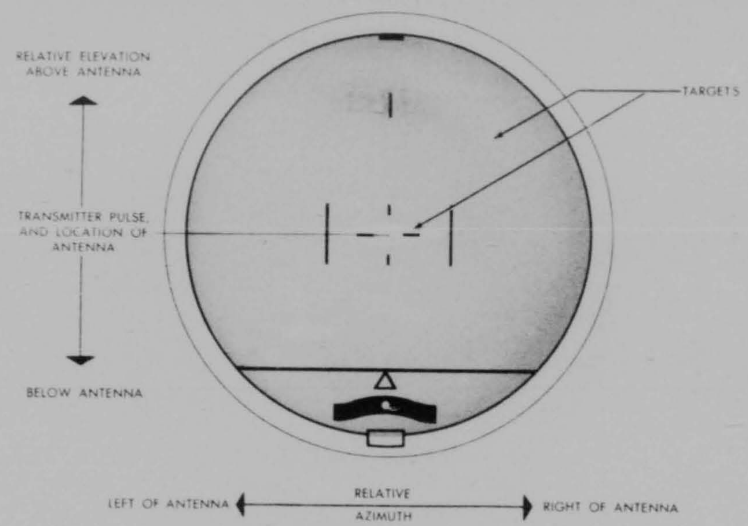

Figure 4-31 C-Type Radar-Scope Display

C-Type

Description: The signal appears as a bright spot at relative azimuth angle and elevation angle. Azimuth angle is the horizontal coordinate and elevation the vertical coordinate.

Data presented: No range presented. Range is read from another type scope. Rate of closing on target may be estimated by wings that grow on target echo as range decreases. Relative azimuth to right or left is read in degrees (sector scan). Relative elevation up or below antenna is read in degrees (sector scan).

Target indication: Bright spot at relative azimuth and elevation.

Type deflection: Electromagnetic.

Application: Aircraft interception. Usually used with a B-type scope (airborne).

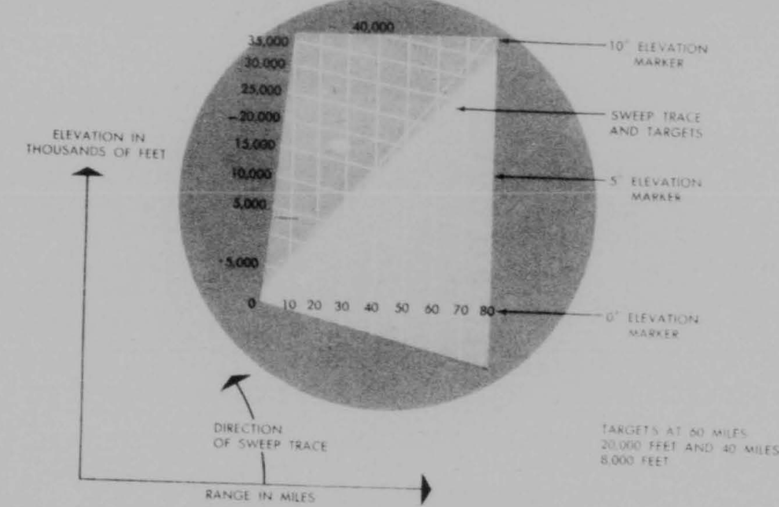

Figure 4-32 RHI-Type Radar-Scope Display

Range Height Indicator (RHI)

Description: The target appears at slant range. This slant range is resolved into range and height. Range is the horizontal coordinate and height above the antenna is the vertical coordinate. A family of calibrated curves on a cursor reads in 1,000's of feet.

Data presented: Range is read horizontally left to right. Azimuth is read from a PPI tube as target appears during the rotation of the antenna. Elevation is read vertically from bottom to top. Trace pivots at origin.

Target indication: Bright spot appears at correct range and elevation.

Type deflection: Electromagnetic.

Application: Height-fading.

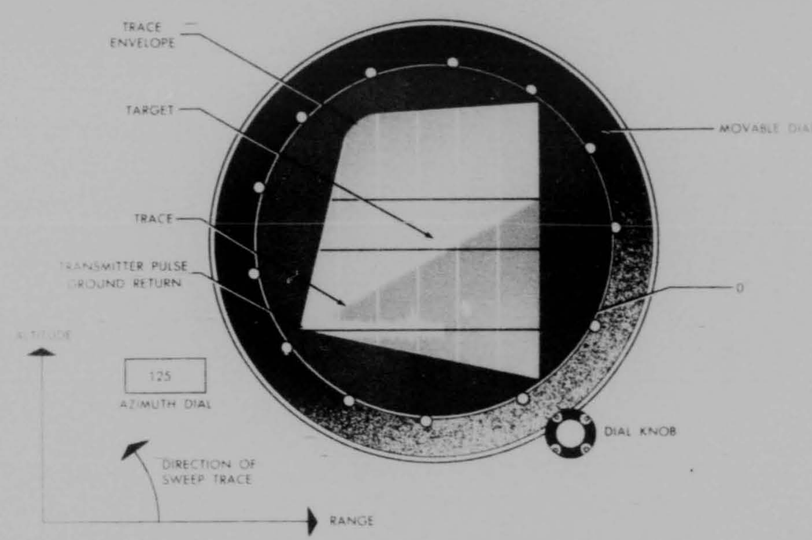

Figure 4-33 Lightweight RHI-Type Radar-Scope Display

Light-weight Range-Height Indicator (RHI)

Description:	The target appears at slant range. The slant range is resolved into range and height above the antenna. Range is read along the horizontal coordinate and height is presented along the vertical coordinate. Height is read from a movable dial on circumference of tube. A movable cursor is placed over target indication. Moving cursor up or down moves dial to correct altitude reading.
Data presented:	Range is presented horizontally from left to right. Azimuth is read from a dial connected to antenna. Elevation is read from dial on circumference of tube.
Target indication:	Bright spot appears at correct range and elevation.
Type deflection:	Electromagnetic.
Application:	Height-finding.

tion; speed and sense; number and type of aircraft; and recognition.

Range

The range of the radar system must be unlimited so that objects may be detected at distances that are nearly half way around the world. These great distances are made necessary by the advent of aircraft and guided missiles of the future which may have speeds in the order of 5,000 knots. It readily can be seen that ranges considered adequate for the relatively slow-flying aircraft of World War II will become entirely inadequate with the advent of aircraft capable of flying faster than the speed of sound. It therefore becomes necessary that radar of the future have ranges much greater than can be obtained at present.

The Joint Communications Board has agreed upon the following five definitions for classifying ground radar equipment by slant range.

VLR (Very Long Range). Equipment whose maximum on a reflecting target of one square meter normal to the signal path exceeds 800 miles, provided line-of-sight exists between the target and the radar.

LR (Long Range). Equipment whose maximum range on a reflecting target of one square meter normal to the signal path exceeds 300 miles but is less than 800 miles, providing line-of-sight exists between the target and the radar.

MR (Medium Range). Equipment whose maximum range on a reflecting target of one square meter normal to the signal path exceeds 50 miles but is less than 300 miles, provided line-of-sight exists between the target and the radar.

SR (Short Range). Equipment whose maximum range on a reflecting target of one square meter normal to the signal path exceeds 50 miles but is less than 150 miles, provided line-of-sight exists between the target and the radar.

VSR (Very Short Range). Equipment whose maximum range on a reflecting target of one square meter normal to the signal path is less than 50 miles, provided line-of-sight exists between the target and the radar.

Azimuth or Bearing

A radar system must be able to determine the azimuth of any target that it is able to detect. The present day radar systems are able to satisfy this requirement to a reasonably high degree.

Elevation

In order to control aircraft from the ground so that the positioning of that aircraft in airspace may be exact, it is necessary that the altitude of the aircraft be determined. The radar should be able to determine the altitude of any target at any detectable range.

Speed and Sense

Information concerning the speed with which the detected object is traveling must be made instantaneously available, along with the sense or direction of travel of the target.

Number and Type

Before effective countermeasures may be taken against any type of action that an enemy may be contemplating, it is necessary that the number of aircraft or guided missiles in the formation be determined as well as the type of aircraft.

Recognition

The radar must be capable of recognizing a target. This information must be automatic and available as soon as the target has been detected by the radar. It is extremely important that the operators on the ground know whether the target is friendly or hostile.

These, then, are the desirable characteristics of the ideal radar. However, present day radar falls far short of this. At present, most of the radar employed for detection or search fall in the medium-range classifications. It is satisfactory in the azimuth determination. Most radar of today does not furnish elevation information as a part of its, regular information. This data is obtained in most cases by the employment of an additional height-finding radar designed for this specific purpose. In addition the range of today's radar equipment is not satisfactory. None of the present radar devices

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is capable of giving immediate information concerning the speed and sense of the aircraft; this is available only after the aircraft has been observed by the radar for a short period of time. This time delay must be eliminated in the future since there will not be sufficient time to employ it with faster-moving aircraft. The operators may make an educated guess concerning the numbers of aircraft in flight but it requires an extremely skilled operator before any degree of accuracy is obtainable by this means.

3. GROUND RADAR EQUIPMENT

Lightweight Radar

The selection of radar equipment for a given purpose is determined not only by the capabilities of the equipment, but also by size and weight factors. For example, warning of the approach of hostile aircraft must be provided for front-line troops. To satisfy this requirement, a light-weight, search-type radar is required. This radar must be light enough to be truck-transportable, and yet rugged enough to withstand rough treatment. A number of radar sets have been constructed with these requirements in mind.

The most successful of these sets are the AN/TPS-1B, for search or surveillance purposes, and the AN/TPS-10 for height finding.

The radar set AN/TPC-1B is a light-weight, medium range (in excess of 50 miles, but less than 300 miles), portable, ground-radar set designed for general search and tracking in range and azimuth, but it will not indicate height or angular elevation. All of the components break down into small packages, no package weighing more than 180 pounds. This provision makes possible movement of the components for short distances by manpower alone. A trained crew of six is able to assemble the equipment from carrying cases to operating position in about thirty minutes. The indicator of this radar may be connected by long cables in order that it may be used at a distance from the other components—from the relative security of a foxhole, for example. Both PPI and A-scan presentation is used. An operating crew of two is required.

Radar set AN/TPS-10 is a lightweight, short range, ground radar designed especially for height-finding of aircraft. It is very useful in regions where ground-clutter or permanent echoes limit the use of other types of radar. This advantage is obtained through the use of a rocking, vertically-narrow beam. The equipment is intended to operate in conjunction with light-weight, search-type radars such as the AN/TPS-1B. Such a combination of equipment makes possible ground control of aircraft. The AN/TPS-10 may be broken down into components, the heaviest of which weighs 170 pounds. It can be installed by a trained crew of six from carrying case to operating position in about thirty minutes. The indicator employs both RHI and A-scan presentations .An operating crew of two is required.

Fixed-Type Radar

The problem of designing and building a radar which will operate for long periods, which will be able to supply information on large amounts of air traffic, and which will be accurate to a high degree has been solved to a certain extent. Three examples of fixed-type radar, that is, not designed with mobility as one of the primary considerations, are discussed below.

The first large capacity radar to be constructed was the AN/CPS-1 or Microwave Early Warning. It is designated "air-transportable" since the components could be carried by a cargo-type aircraft. It is a search radar employing microwaves capable of low and high altitude coverage. It provides highly accurate range and azimuth information. The problem of site selection is largely overcome by the frequency employed. Time of assembly from crates to operating position requires a minimum of three days for a trained crew of ninety men.

The information derived from this radar is presented in two ways. Search information is presented by B-scan indicators. Information for the use of personnel charged with controlling aircraft is presented on PPI-scopes. As many as five B-scan indicators with adjustable azimuth coverage from 40 to 100 degrees and 30-, 80-, and 100-mile sweeps in any sector from 0 to 200 miles may be employed with each MEW. The B-scan indicators are normally set so that each covers 90° or less. In this way, B-scan No. 1

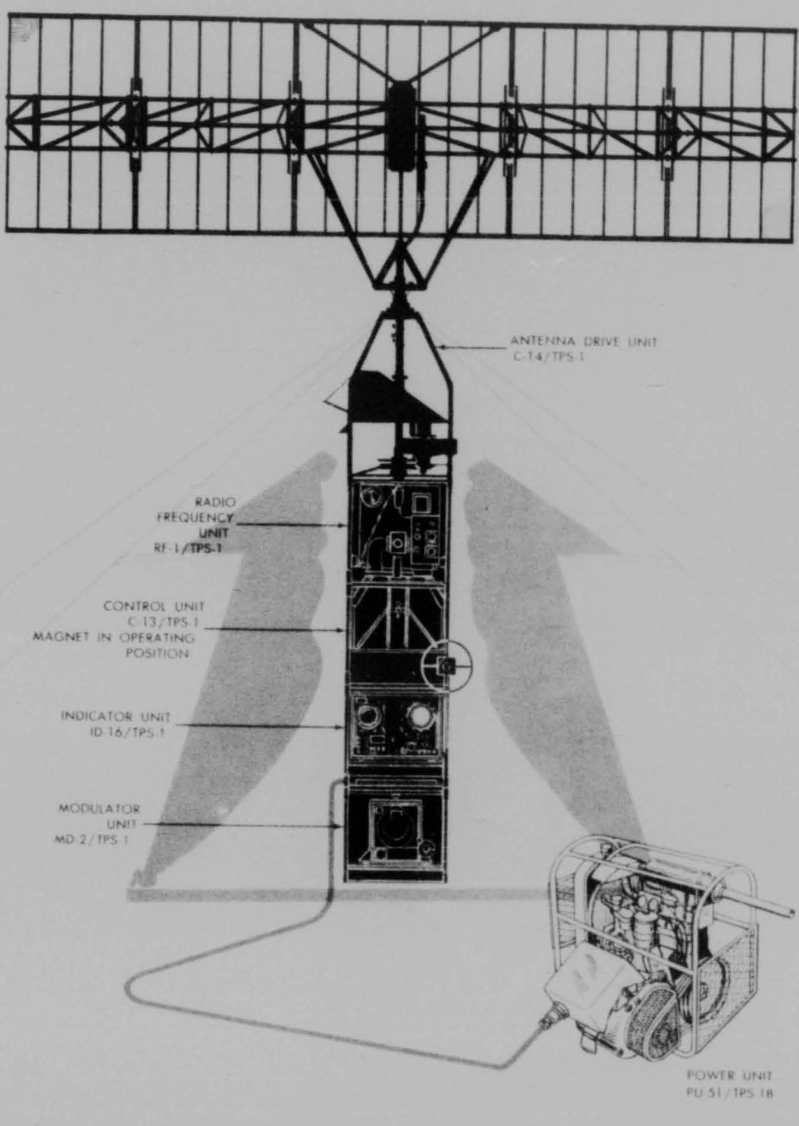


Figure 4-34 Radar Set, AN/TPS-1B

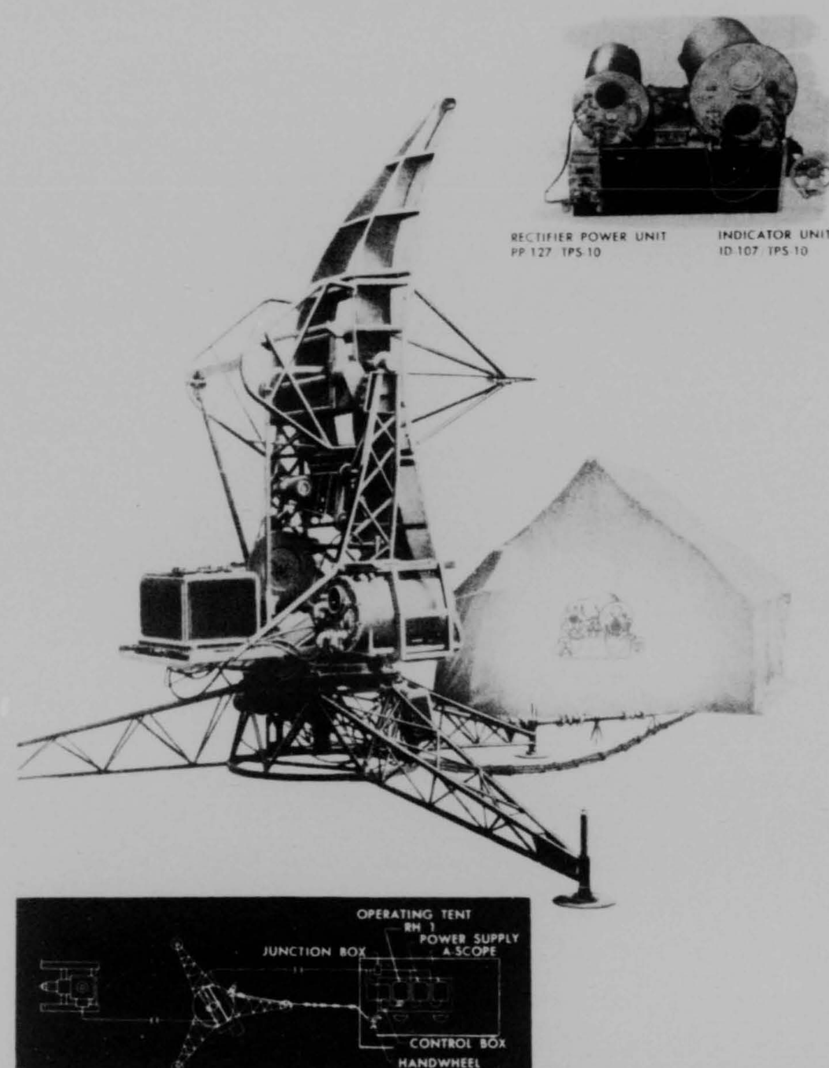
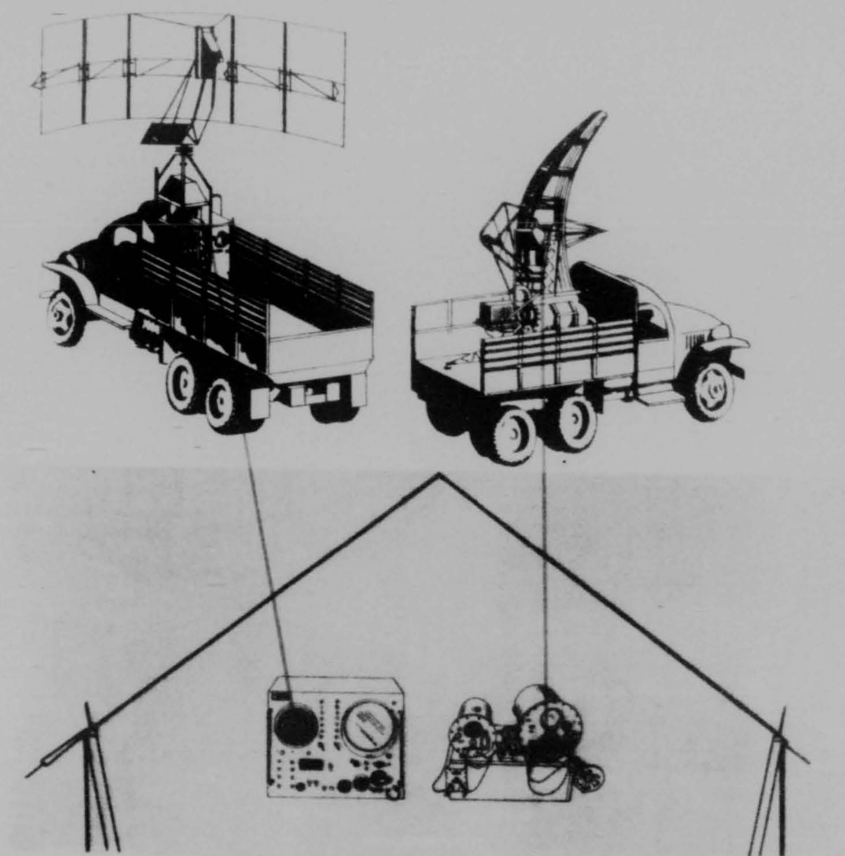


Figure 4-35 Height Finder Radar Set AN/TPS-10



searches from 0°-90°, B-scan No. 2 searches 90°-180° and so on. B-scan No. 5 may search 360° for the purposes of a supervising operator, or may be employed as are the other indicators. This method of operation reduces the amount of airspace actually searched by each operator. Because of this, each operator is subject to less eyestrain and is able to watch more closely for target indications in his own sector.

It is not within the scope of this text to describe radar station operation. Let it suffice to say that the PPI-scope is more efficient from the control-of-aircraft point of view, and that the radarscopes as employed with an AN/CPS-1 are grouped separately from the B-scan indicators.

Inasmuch as the MEW is incapable of determining the height of targets, the development of a suitable height-finding radar was essential. While the AN/TPS-10 could be employed with the MEW, it was not designed for sustained operation.

The radar set AN/CPS-4 answers the need for a companion set for the MEW. It is an air transportable, short-range, ground-radar set designed to find heights of aircraft. Like the AN/TPS-10, the beam of the AN/CPS-4 is

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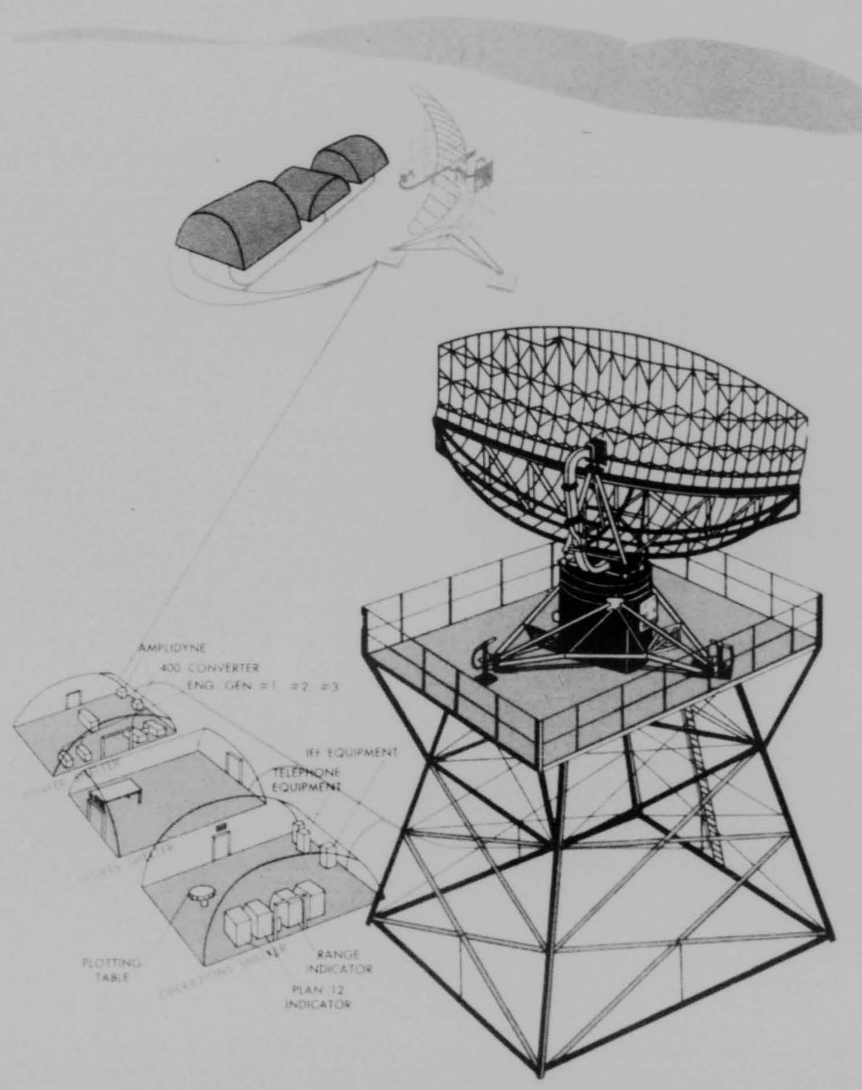

Figure 4-36 Radar Set, AN CPS-5

vertically narrow. This equipment is electrically tied in with the search set enabling three-dimensional data to be available for the control of aircraft. A trained crew of thirty men can assemble the AN CPS-4 in one day. The set employes one RHI, two PPI's and two A-scopes for monitor and test purposes. Three operators are required for this equipment.

The AN CPS-5 incorporates the features of heavy, early warning sets with the portability of the lighter weight sets. Designed for early-warning operations, the AN CPS-5 can be installed in one day with a crew of thirty men, comparable to the normal operating strength of a lightweight early warning unit. The set operates at a lower frequency than the AN CPS-1 (1,300 megacycles) but has almost the same maximum range. When properly sited, a range of 200 miles can be expected. While it does not afford height-finding facilities in itself, when incorporated with the regular height finders adequate control facilities can be given. The entire unit weighs nineteen tons as compared with the sixty-six tons for the AN CPS-1.

The ultimate in search-control radars of today is the V-Beam, the AN CPS-6. This is a microwave, ground radar designed for search, control, general air traffic control functions. It is able to find heights of aircraft by the use of a V-shaped radiation pattern. Hence, its nickname, "V-Beam." This radar is characterized by its high traffic-handling capacity, relative freedom from sitting difficulties, long-distance coverage at a low angle, and high resolution with moderate accuracy. Time of assembly from crates to operating positions is approximately one week with a trained crew of ninety men. A large number of indicators may be employed with this equipment. Normally furnished with each set are eight PPI, four RHI and seven B-scopes. As with the AN CPS-1, the large number of radar-scopes employed adds to the accuracy of interpretation of information displayed.

Identification and Recognition

It is necessary, for tactical reasons, to be able to determine the identity of a target. Just as a sentry must challenge everyone approaching his post, so must the radar operator challenge all targets detected by his radar equipment. Early recognition is imperative to avoid alerting personnel and equipment unnecessarily.

The problem of identification is to convey intelligence, by means of an electronic device, from the detected object to the detecting device for the purpose of ascertaining the identity of the target. In other words, the problem involves providing each ship, aircraft, guided missile, armored vehicle, and ground unit with some electronic means of showing its identity. It is also necessary, to provide these same units with means for obtaining the desired information.

In addition to the usual problems involved in identification, the identification of aircraft presents some peculiar problems of its own.

First, the difference between two similar terms must be established:

Identification is the indication by an act or means of one's own friendly character or individuality.

Recognition is the determination by any means of the friendly or enemy character, or the individuality, of another unit or individual. Recognition includes determining the type of target (aircraft, ship, tank, etc.) and its nationality.

Identification and Recognition System. At the present time, no system of identification and recognition is 100 per cent satisfactory. The problem is to convey intelligence by means of an automatic electronic device.

To accomplish this identification, a system of three components has been developed. One component of the system is used for transmitting the challenge. The second is used for receiving the challenge and returning the proper coded reply or identification. The third component is used to receive and display the coded reply. The challenging transmitter or interrogator, at one location, sends out a signal which is received at the distant station. This signal causes the distant station to return a characteristic reply. This reply is received at the initial location and is presented to the operator in such a manner that he is enabled to recognize the target—actually, the distant station.

As radar, at present, is the means of detecting a target at long ranges, the iden-

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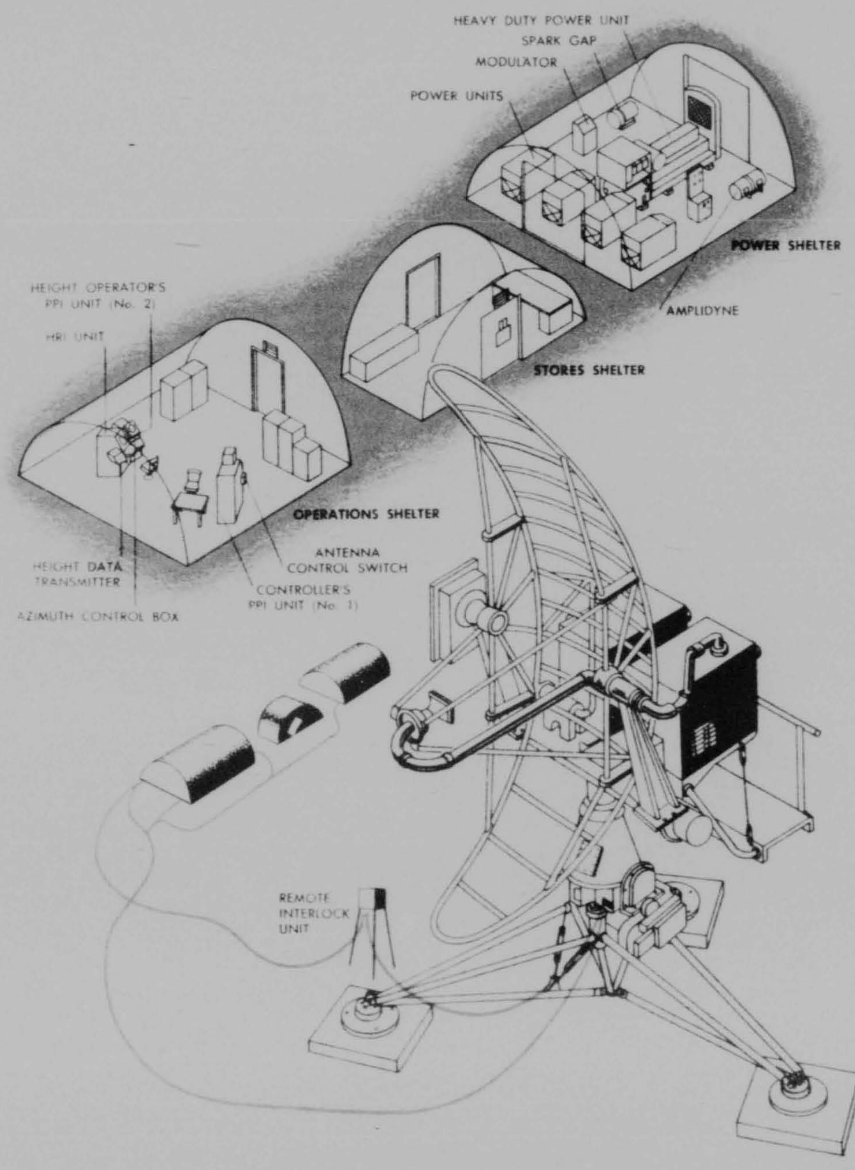

Figure 4-37 Radar Set, AN/CPS-4

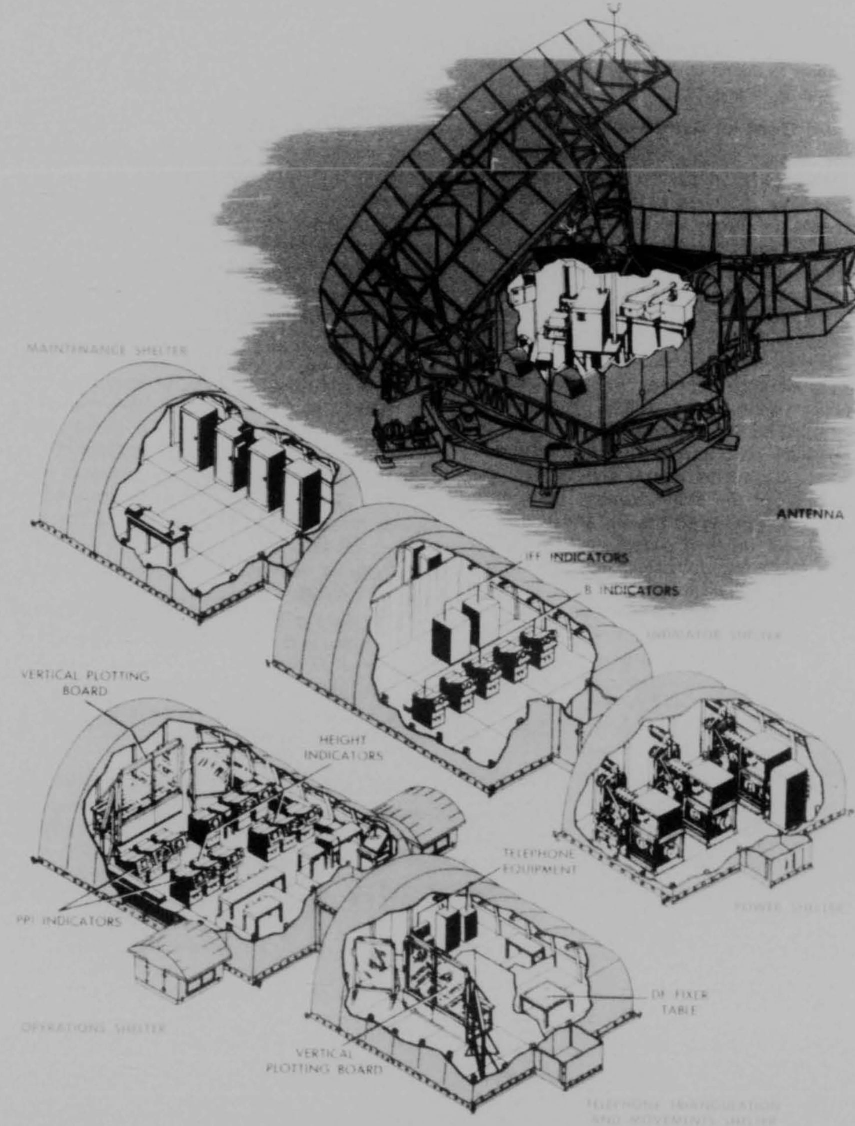

Figure 4-38 Radar Set, AN/CPS-6 (V Beam)

tification and recognition system is usually interconnected with the search radar. The display may be an integral part of the search radar set or may be separate. When separate, the display is independent of the radar equipment, but is located nearby.

Ground Control Approach (GCA)

A third type of ground radar for use by the Air Force has been developed. This is the GCA system which provides facilities for directing the movement of aircraft in the vicinity of an airdrome and over a predetermined glide path for a safe approach to the proper runway, under conditions of adverse visibility. Accurate and continuous information regarding the location of incoming aircraft with respect to the predetermined glide path is presented to the ground operators in the form of range, azimuth, and elevation data by the radar components of the system. This information is interpreted by the operators as lateral and vertical deviations from the predetermined glide path for the type of aircraft making tne approach. Instructions are then passed on to the pilot by a radio communications system in the form of corrections for him to make in order to keep on the proper glide path. With the aid of these instructions, the pilot is able to bring his aircraft to a point in line with the runway and below the ceiling, and prepared to make a visual landing.

In addition to providing the desired information concerning the approach, the system under favorable terrain conditions is capable, when well sited, of furnishing range and azimuth information to a pilot within 30 miles and up to an altitude of 4,000 feet. This information is utilized in controlling aircraft and positioning them for the final approach.

The GCA system differs from previous systems in that all the specialized equipment for effecting the approach is located on the ground. The only equipment required in the aircraft is a two-way radio communications set operating in either the HF or VHF band.

4. AIRBORNE RADAR EQUIPMENT

General

With the rapid development of air power during World War II, it soon became evident that to carry on the air war under all weather conditions both day and night, it would be necessary to devise some method to make such operations increasingly effective. Broadly speaking, the problem faced by the Air Force was to find equipment that would permit all-weather operations, and that would provide each aircraft with the special equipment which would permit it to function at its maximum range and its maximum effectiveness.

The need for twenty-four hour operations poses special problems such as flight safety, navigation, bombing, and landing aids, which must be solved before this type of operation may be successfully undertaken on any large scale.

In addition to the daylight-darkness factor, the additional problem of weather must be taken into consideration. To approach maximum effectiveness, the Air Force must be able to mount its attack regardless of the weather in the target area, the weather conditions along the route, and at the home bases. Some of the Air Force special requirements are these:

Precision Navigation. There must be a device (or devices) permitting precision navigation during instrument flight conditions, when neither ground observations (pilotage) nor celestial observations can be obtained.

Accurate Bombing. There must be a device to permit accurate bombing of targets when the target is obscured by clouds, smoke, haze, or dust.

Safe Landing. There must be a device or system to aid the aircraft in landing at the home bases when the visibility and ceiling are below the safe visual conditions. The Instrument Landing System and the Ground Control Approach, although not perfect, are currently the best available for the purpose.

In addition to the advantages to be obtained by devices that permit all-weather and around-the-clock operations, there are other advantages which may be obtained through the employment of effective electronic aids.

Among these are:

Fewer aircraft will be lost in operational accidents.

Each aircraft will waste less fuel if it can

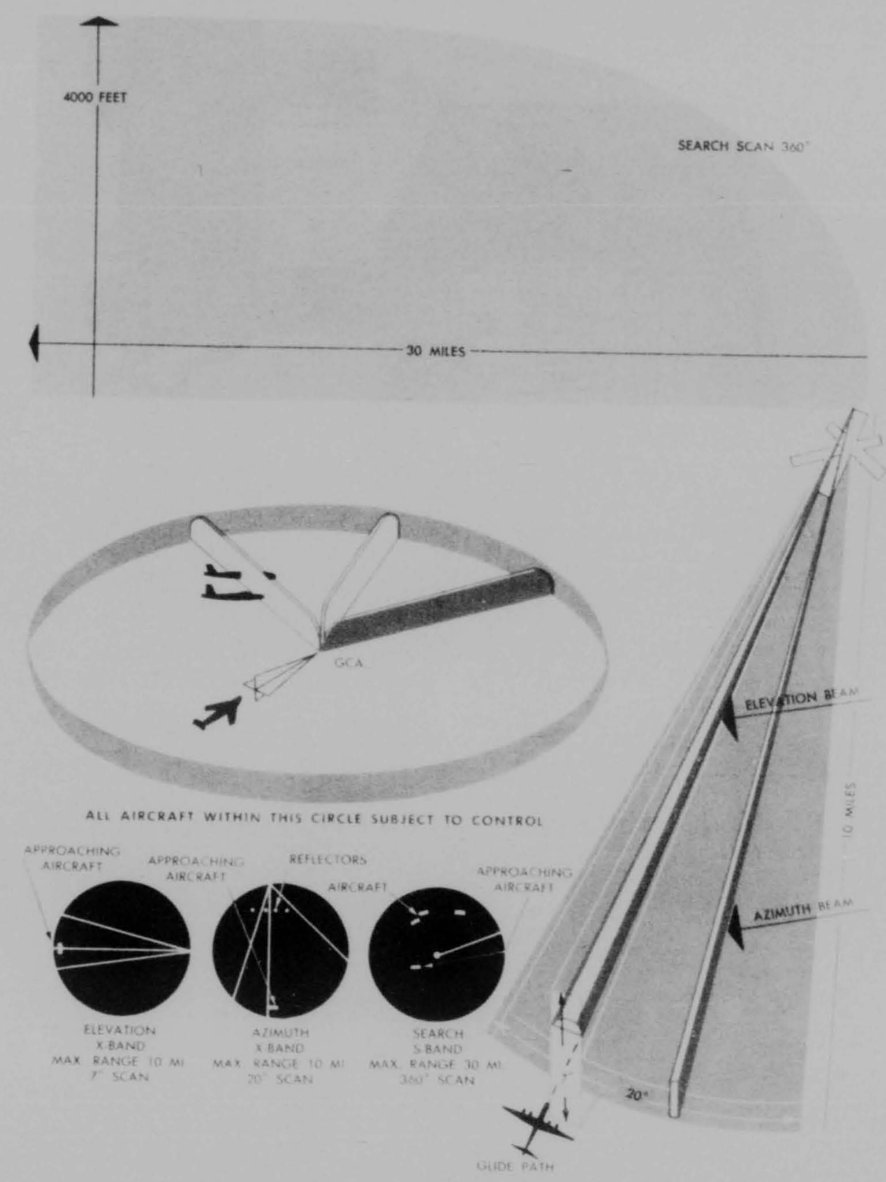

Figure 4-39 GCA

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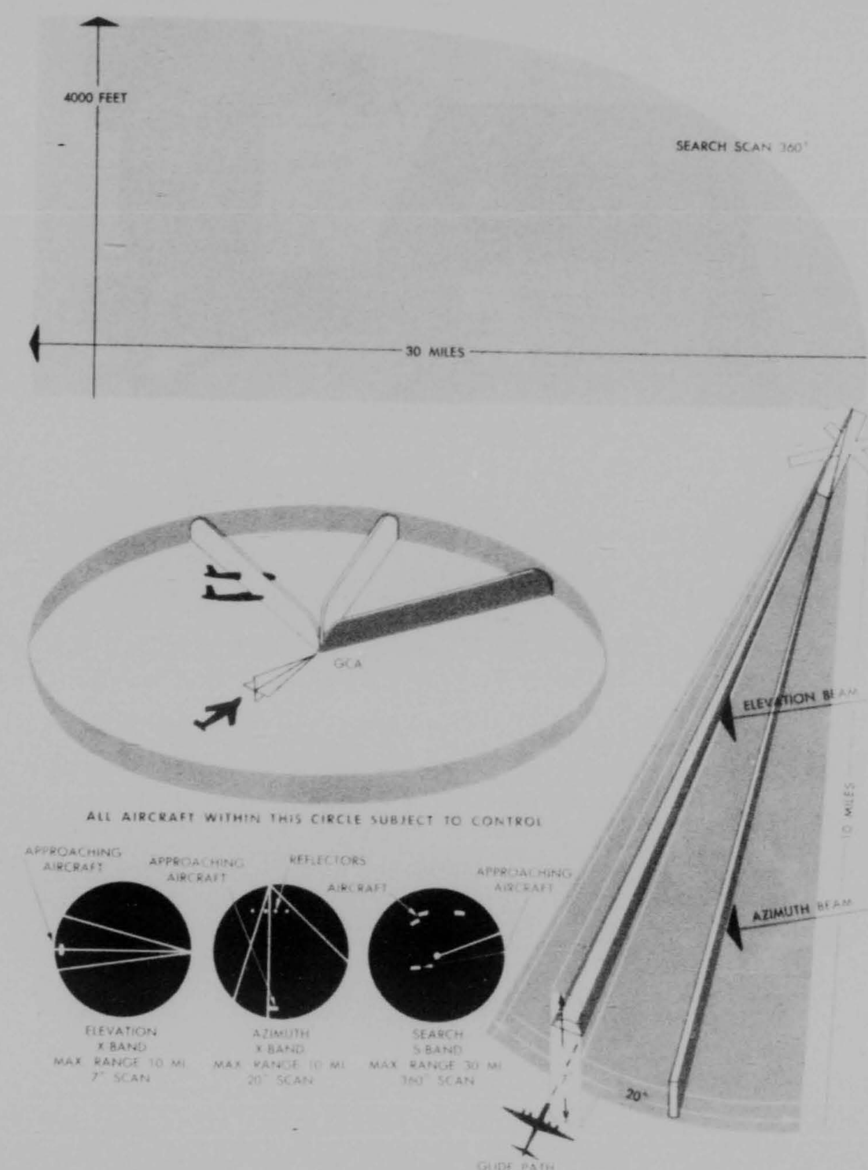

Figure 4-39 GCA

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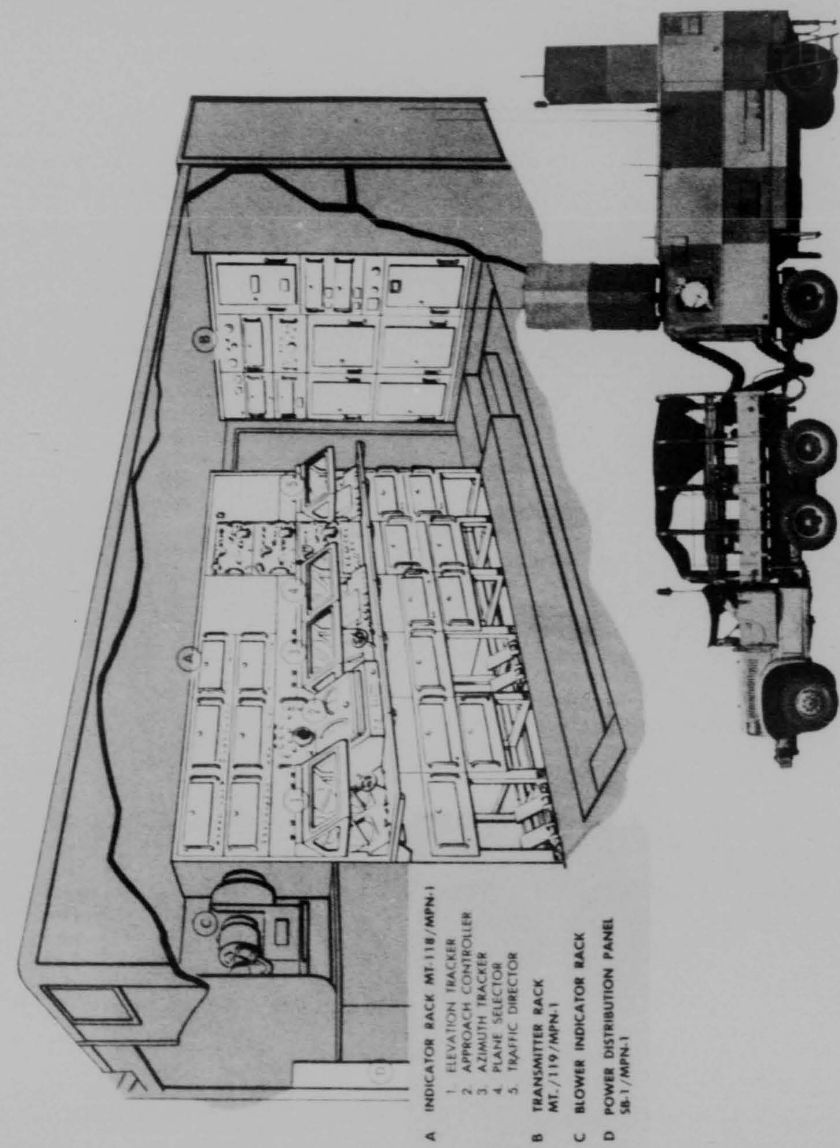


Figure 4-40 GCA Operations Trailer

Figure 4-41 Aircraft Radar Aids

be kept on a predetermined course. (This will permit the aircraft to carry a larger bomb load over the same distance or allow the radius of action to be increased when carrying a fixed fuel load.)

Scheduled rendezvous and assemblies can be kept.

The selected bombing target can be found, regardless of the conditions which exist at the bombing area.

The bomb run can be made at the proper time and in the proper direction.

Heavy flak areas can be avoided since the aircraft can be navigated around these and back on the proper course.

The aircraft can return to its home base with a minimum of difficulty.

In this discussion, only the broad requirements of the Air Force airborne radar equipment will be considered. The subject of special requirements of the Strategic, Tactical, and Air Defense Forces, will not be considered since these special requirements are adaptations of the same basic principles that will be discussed. Generally speaking, the requirements of any of these will be the same.

From a broad study of the mission of the United States Air Force, it becomes readily apparent that certain specific needs must be met. Chief among these are:

Physical requirements.

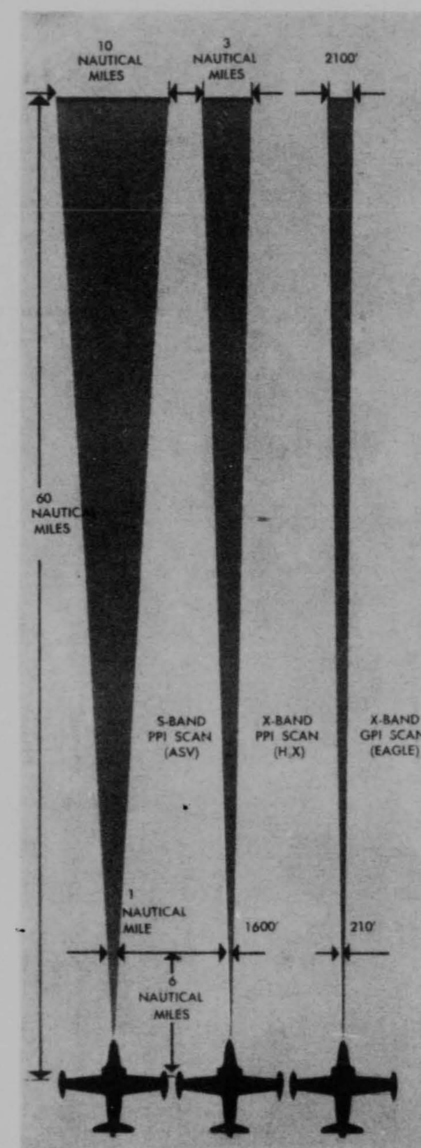
Navigation requirements.

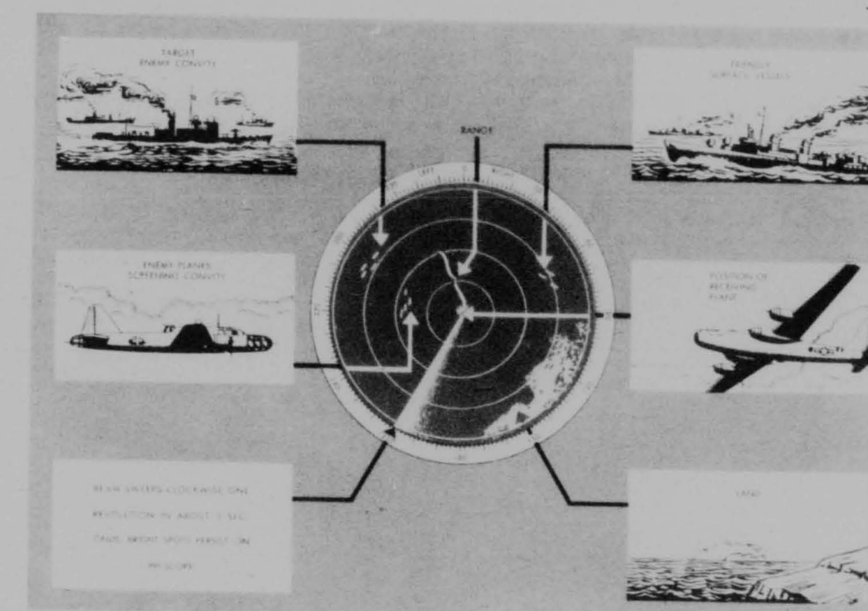
Bombing requirements.

Airborne defensive requirements.

Physical Requirements

Since the equipment must be installed in aircraft, there is a limitation on the total weight of the equipment. As the weight of the installed equipment is increased, there must be a corresponding reduction in the total load of the aircraft. Usually, the reduction can be applied only to the bomb load or fuel load, in either case causing a reduction of bombing effectiveness or range. With the very large types of aircraft employed in the bombardment field, the weight limitation will not be quite as critical as with smaller types of aircraft. It will, of course, reach its most critical stage with fighter-type aircraft. It is a factor that can never be neglected. Also, since the equipment must be installed in an aircraft, the component parts must be of such size that they can be fitted into the aircraft with a minimum disturbance of the basic interior design. Since some types of radar equipment require the presence of an additional crew member, the installation must take into account the space required for the radar operator. Again, the space requirements are more critical in the smaller types of aircraft than in the larger aircraft.





A further consideration that must be made is the effect on the flying characteristics of the externally mounted portions of the equipment. Usually, the antenna is mounted on the outside of the aircraft with a resulting increase in drag and a decrease in the air speed. This problem of drag becomes increasingly important as the speed of the aircraft increases since the drag increase is proportional to the second power of the velocity.

A third major physical requirement for airborne radar equipment is the ease or simplicity of operation. In all cases, the airborne radar equipment must be designed so that one man can operate it. Since the space for installation is limited, control and display units are designed to permit operation from a single position.

A fourth physical requirement imposed upon airborne radar equipment is that it must be entirely airborne and must not depend on any ground components or installations. An exception is the employment of airborne equipment with homing beacons. This is necessary since the range of operation of the aircraft will be far beyond the distance at which ground transmitted signals can be received.

The fifth physical requirement to be met is the initial electrical power supply of the aircraft. The power supply within the aircraft is comparatively small, is of low voltage, and is direct current. The equipment must be designed so that its power requirements are small and do not require the addition of more generators to the aircraft. The final requirement of airborne radar arises from the altitude at which it must work.

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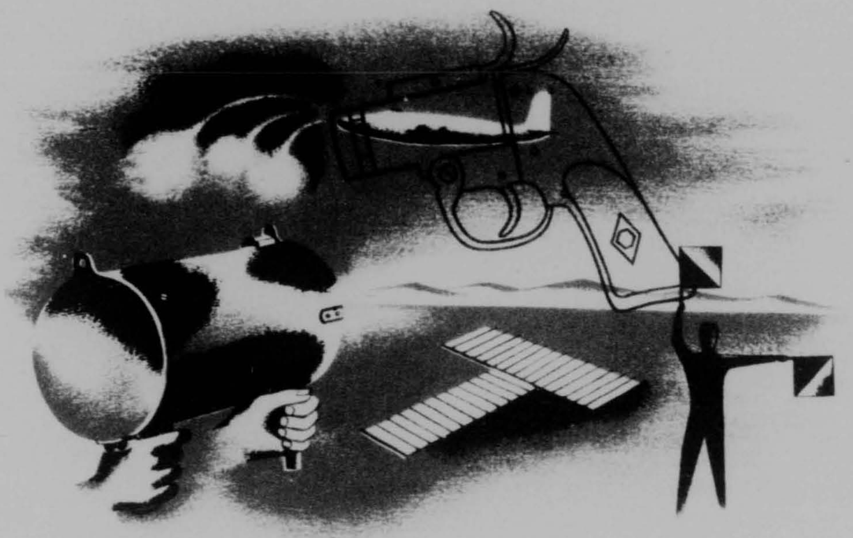
Owing to the decrease in atmospheric pressure as the altitude of flight increases, special provisions must be made for this decrease in the effect of reduced pressure. The reduction of pressure in the atmosphere causes the electrical equipment to arc over and become inoperative because of electrical breakdown.

The solution of the problem imposed is not one for the communications officer and is mentioned only as a matter of interest. The solution of this problem is one that requires the application of sound engineering principles. As previously discussed, it is readily seen that there are many conflicting items and the practical solution is one of compromise. It is to be hoped that the future developments, which will not be made under the pressure of war necessity, will be considerably more satisfactory than the present equipment. Before a completely satisfactory solution may be derived, great technical advances will have to be made in the improvement of materials and methods, as well as in circuit designs.

Other Requirements

Equipment designed to satisfy the navigation, bombing and airborne defensive requirements is so varied and in such variety that this subject will not be discussed here. It will be included, however, in Volume III, Chapter 5, in the sections on types of equipment employed in functional communications systems.

CHAPTER 5 - VISUAL AND AURAL COMMUNICATIONS



SECTION 1 - MILITARY USE

CAPABILITIES AND EMPLOYMENT

General

Visual communications includes all signals received by the eye regardless of transmission method. However, only the more important methods of visual communications, lights, flags, pyrotechnics, panels, and airplanes will be discussed here.

In areas served by other means of communications, visual communications is an auxiliary, supplementing wire and radio. The necessary equipment should be readily accessible at all times and in operating condition. For small isolated groups or units which are not equipped with electrical means of communication, the situation may sometimes be such that visual signaling with any means available is the only method possible. Its use depends upon the type of warfare, proximity of the enemy, terrain and weather. The relatively slow speed of transmission renders visual signal communications less suited for transmitting long messages than other means, but it is well adapted to transmitting prearranged messages and code groups over short distances. Visual signaling is especially applicable for use from front lines to the rear, from ground to air, and from ground to a vehicle in motion. The success of visual communications depends upon training, previous preparation, distribution of codes and prearranged messages.

Between Ground Stations

Attempts to attract attention of personnel with whom communications is desired must be persistent. All personnel must be trained to be on the alert for prearranged signals. If other effective means are available, visual communications should not be used, especially when it is likely to disclose a position or to draw fire on other troops. Where signals are being sent which are likely to disclose a position or to be seen and read by the enemy, care must be taken not to disclose information which may enable the enemy to take countermeasures in view of the time factor involved. Great care must be exercised in the selection of locations for visual signaling stations, especially those transmiting from rear to front.

Advantages. The advantages of visual communications between ground stations are:

Rapidity with which stations can be installed.

Speed with which short messages and prearranged signals may be sent.

The light weight, simplicity, and portability of the equipment.

Absence of need for metallic circuits between stations.

Disadvantages. Disadvantages of visual communications between ground stations as compared with wire and radio are:

Slowness, hence poor adaptability for sending long messages.

Dependence upon mutual visibility.

Difficulty of locating companion station, attracting its attention, and insuring receipt for traffic.

The vigilance necessary by operators to avoid missing signals.

Limited range.

Air-to-ground Usage

Visual communications from the ground to aircraft in flight is possible by use of panels, pyrotechnics, flags, and signal lamps. The aircraft may reply by radio, dropped messages, pyrotechnics, lamps or limited wing signals. An example of visual communications between ground and air in World War II was the marking of friendly front lines with pyrotechnics such as colored smoke.

2. METHODS

Lamps

Visual signaling by lamps is used more in the Navy for communications between ships and between ship and shore, than in the Army Field Forces or the Air Force. The equipment used for lamp-signaling or blinker is usually portable. It consists of a lamp which may be mounted on a tripod or carried by hand, necessary cords, box with necessary dry cell batteries, and a key for sending. The code used in the blinker system is the International Morse code. (Figure 5-1) Another very important use of lamps for signaling is in airdrome control towers. Lamps used for airdrome control are different from the blinker lamps in that they employ the use of two colors, red and green, and generally do not employ the use of other than color codes. Normally, the control lamp is used only when radio communication is not available or strict radio silence is required. By using red and green lights, the operator can give directions to craft in the air and on the ground.

Flags

There are two types of flag signalings; semaphore and wigwag. Suitable equipment is issued for signaling by either method. If no standard equipment is available, strips of cloth tied toward the outer end of sticks of wood or bayonets will serve for semaphore flags. For short ranges, when the use of flags would be unduly conspicuous, the hands or arms, or the headdress or handkerchief held in the hand may be used. The semaphore flagmen use the semaphore code. (Figure 5-2). Wigwag flagmen use the International Morse code.

Semaphore. A proficient semaphore flagman should be able to transmit and receive at the rate of 125 characters per minute at medium ranges. Under favorable conditions and with the aid of field glasses, semaphore flags can be read up to 2,500 yards.

Wigwag. For general use in lower units, wigwag signaling is more appropriate than semaphore because transmission is possible with improvised equipment and does not require an operator to expose himself by

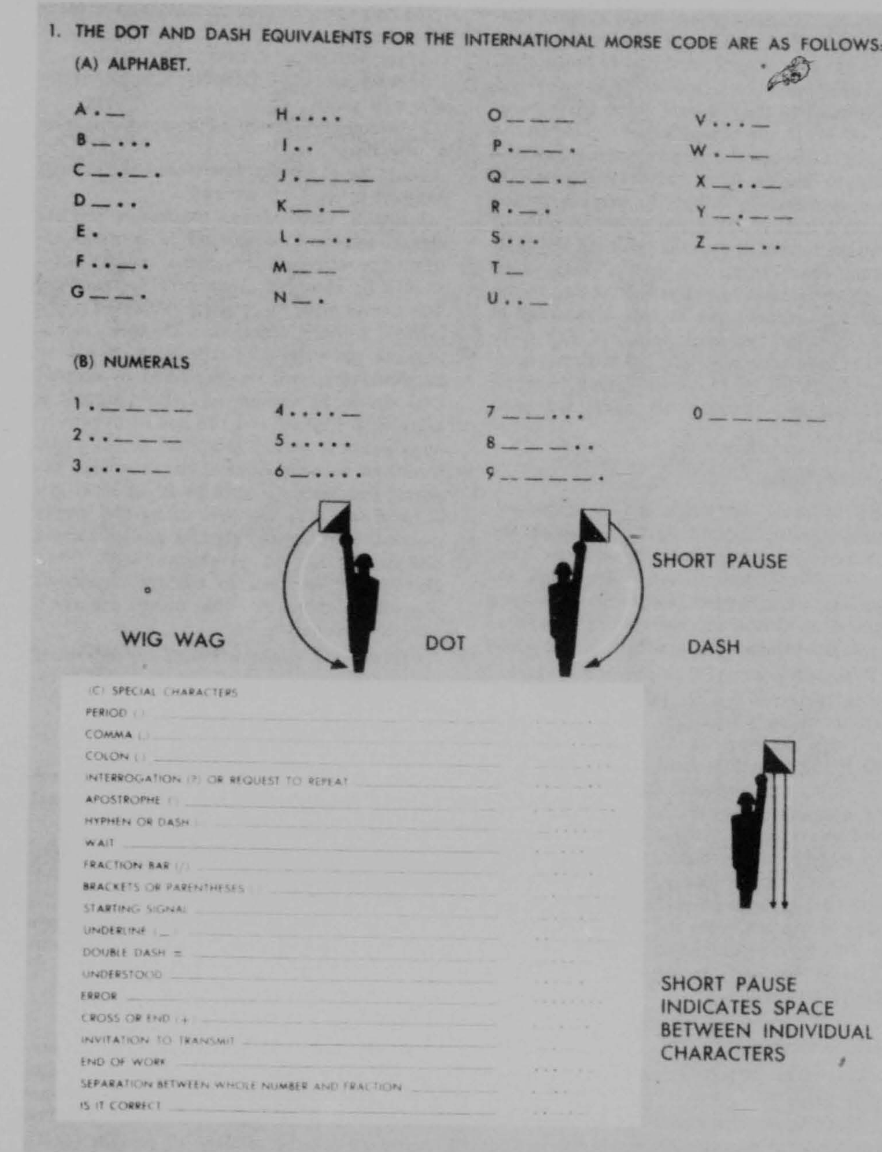


Figure 5-1 International Morse Code

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standing. Since wigwag flags, radios, telegraphs, and signal lamps employ the International Morse code, training is facilitated. A dot is made by a motion from overhead downward to the sender's right, through an arc of 90° in the plane perpendicular to the line of transmission and returning immediately to the starting point (overhead). A dash is made by a similar motion to the sender's left. A short pause in the vertical position indicates spacing between the individual characters. The end of a word or group is indicated by dipping the flag to the operator's front; the end of a message is indicated by two such motions. For communication with aircraft, the wigwag operator faces the airplane continuously while transmitting, turning his body for such purposes.

Pyrotechnics

Pyrotechnic devices used for communication are the ground signal projector, the pyrotechnic pistol, aircraft, and the Very pistol. Pyrotechnic devices are used for sending prearranged messages requiring immediate action or when other means of communications are uncertain or too slow.

Pyrotechnic Pistol. The pyrotechnic pistol, aircraft-type, is for use in airplanes. It consists of a heavy frame or receiver only, the cartridge serving as the barrel through which the signal is fired. The cartridge is about one and one-half inches in diameter and contains either a star cluster or a star blinker signal of various colors. The cartridge is inserted into the receiver of the pistol, held outside the airplane and fired. After firing, or in case of a misfire, the cartridge is ejected from the pistol. The pistol may be held in one hand and fired, but because of the fairly severe recoil, both hands should be used.

Use. Some of the principal uses of pyrotechnic signals are:

To cause artillery fire to commence, or to lift.

To indicate the arrival of certain front line units at certain points on the terrain.

To acknowledge receipt of lamp or flag transmission by a visual station which is not permitted to use lamps or flags.

To call for a display of markings or identification panels.

Identification of friendly aircraft.

Identification of friendly armored vehicles and units.

Intercommunication of armored vehicles and units.

Marking of enemy front lines for ground support by tactical aircraft.

Message Transmission. Meanings are assigned pyrotechnic signals in communication operation instructions (COI) and should be changed frequently for secrecy. The names given in catalog listings of pyrotechnic signals, together with their meanings as prescribed by the unit or higher headquarters, will be published in current COI. Since the number of distinct signals is extremely limited and the use of pyrotechnic signals is largely confined to the front lines and to emergencies, the meanings assigned invariably should be those most important to front-line operations and emergencies. Pyrotechnic signals are extremely difficult to see in bright sunlight. They should not be used to control important operations unless no other means are available or practicable.

Precautions. Observation of the following precautions will prevent the misuse of pyrotechnics:

Signals should be distinct from one another.

The most readily discernible signal should be assigned the most important meaning.

Promulgation and distribution of communication operation instructions pertaining to pyrotechnics should be timely.

Each unit commander should designate an officer to be responsible for the use of pyrotechnics by that unit.

Panels

Panels are used only as a means of communications from ground to air. They consist of either black, white, or tangerine-colored material and vary in size. The standard size is usually 12 feet in length and 2 feet 4 inches in width. Care should be taken in selecting the panel display area. The ground selected should be a fairly level

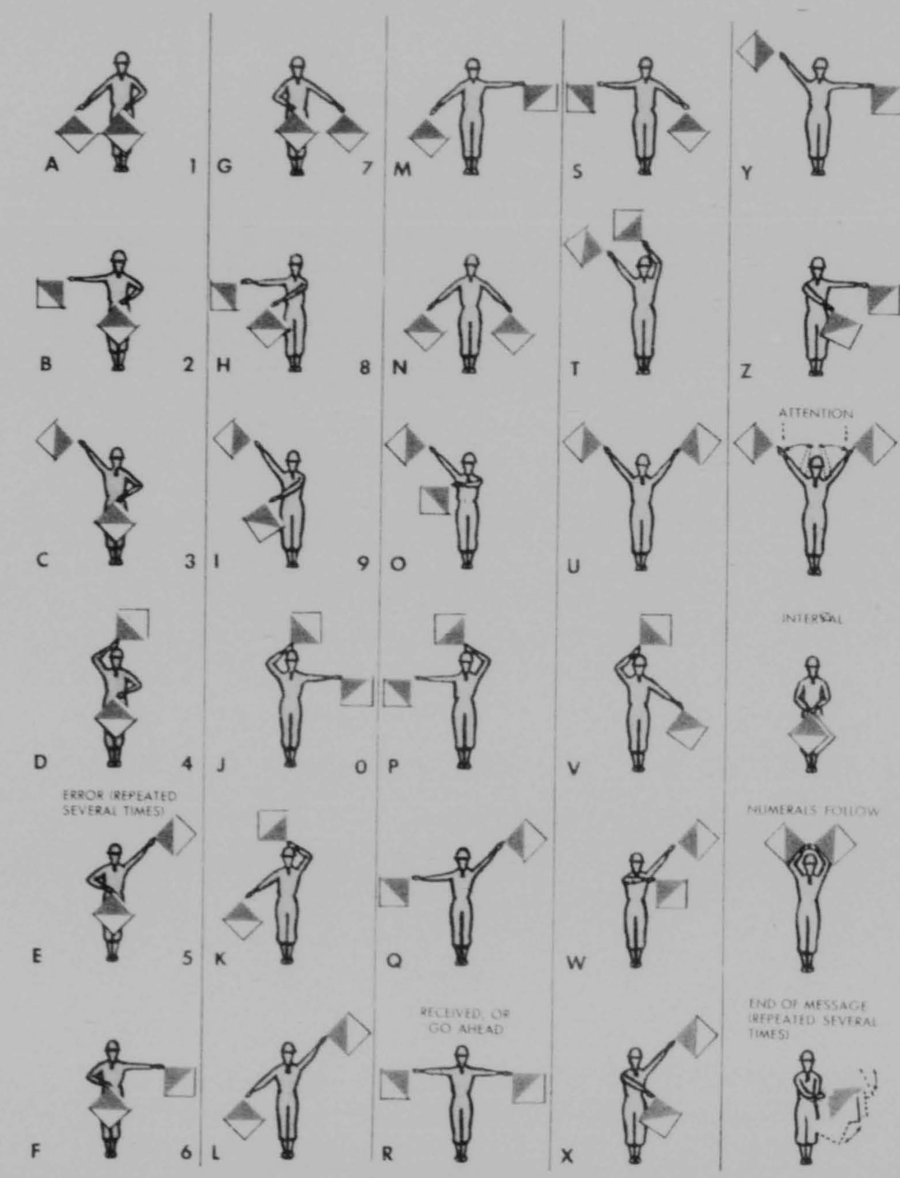

Figure 5-2 Semaphore Code

open space, free from rocks, high weeds, brush and removed from high trees and bodies of water. It should be screened from hostile ground observation if possible, but so located that the panels may be seen by airplane at wide angles from the vertical. The panels should be displayed in the best light available and be so placed that they will not be obscured by shadows. The basic visual components are used as indicated in Figure 5-3.

Airplane Maneuvers

In an emergency, when a ground station is not equipped for radio reception or when the radio transmitter of an airplane is silenced or out of commission, an airplane may communicate to a limited degree with a ground panel station by means of various maneuvers of the airplane while in flight. However, such signals are extremely limited in number. No standard code has been developed for this means of communication but any code used should be practicable of performance by the airplane used and preferably be prescribed in communication operation instructions. Individual units have devised such codes by prearrangement with other units designated to operate with them. Adjustment of the fire of field artillery batteries by the use of panel signals and airplane wing signals exclusively is rapid and often practicable.

Communications By Sound

The audible transmission of intelligence by mechanical or acoustical devices, excluding speech, and their direct reception by ear, is defined as sound communications. Such common sound-producing devices as whistles, horns, bugles, sirens and rattles, and the sound produced by small arms, artillery, and motors of airplanes in flight are frequently used for signaling. Orders, information, and other prearranged messages are represented by bugle sounds. Other sound-producing alarm devices are issued for use in the event of enemy gas or air attacks. The gas alarms are percussion sounds, such as those produced by bells, triangles, or iron rails which are struck rapidly and continuously. The air attack alarms are three long blasts of a whistle, motor horn, siren, or klaxon repeated several times. The chief value of communications by sound is the resulting economy of time, personnel, and equipment when utilized for alarms for attracting attention, and for the transmission of short prearranged messages.

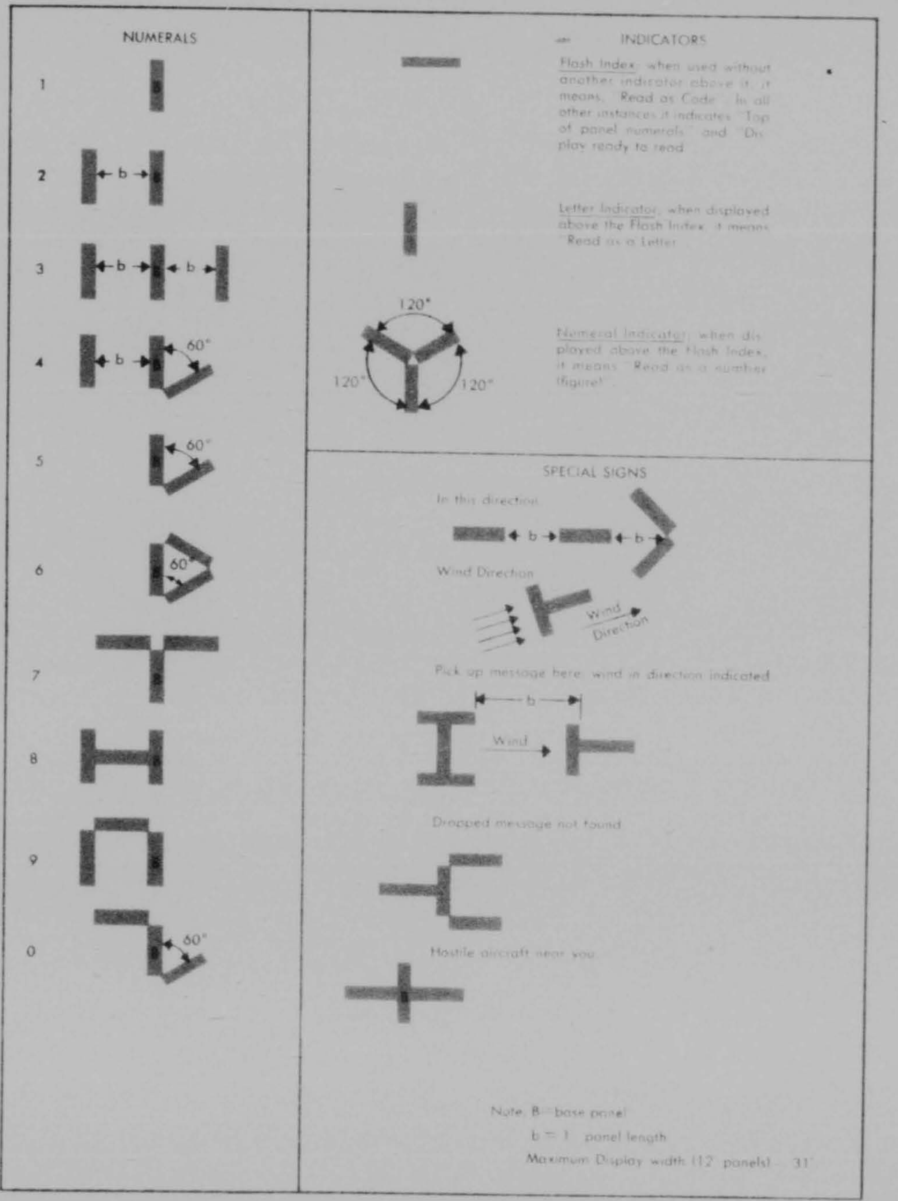

Figure 5-3 Panels

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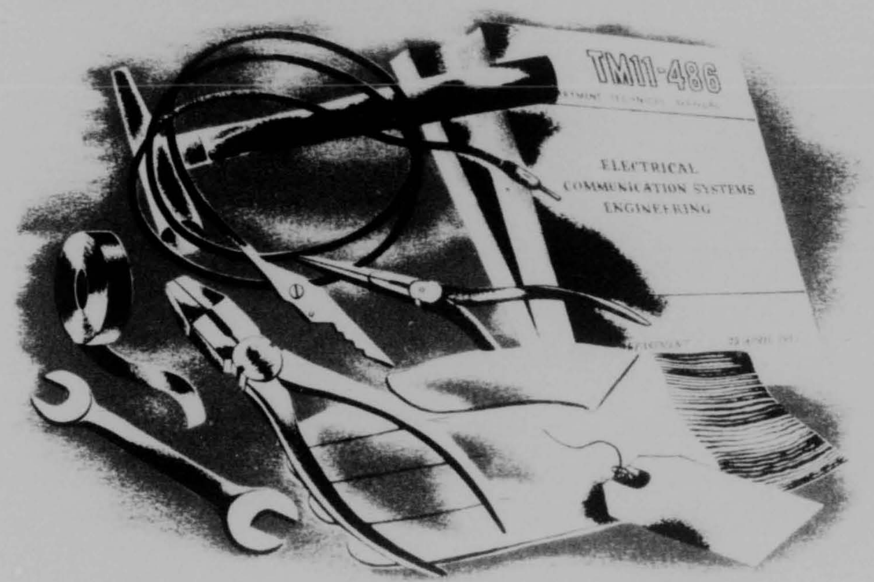
CHAPTER 6-COMMUNICATION SUPPLY AND MAINTENANCE



1. GENERAL

One of the important functions of communications is in the field of logistics. Emphasis here is placed on the communications officer at squadron level; the operation of a communications supply section and the maintenance facilities required is the responsibility of the unit communications officer. It is true that the actual work is often done by a specialist in the field of communications supply or maintenance, but the responsibility falls upon the communications officer who reports to the commander. At squadron level, the supply and maintenance functions in communications are usually the responsibility of a single officer who also has duties in the communications fields of section administration, operation, intelligence, and inspection.

As this assignment involves a multiplicity of detail, the communications officer must have a basic knowledge of Air Force supply, maintenance, and inspection systems. This chapter, therefore, will indicate the scope of these subjects as they apply to the field of communication.

2. PUBLICATIONS FOR COMMUNICATIONS

The communications officer, in his continuous effort to keep abreast of existing and ever-changing conditions, new developments, policies, and operational or administrative procedures, must make frequent reference to literature of a general and technical nature. It is therefore important that he have a sound basic knowledge of the material contained in the various military publications in order to properly acomplish his work.

In recognition of this need, the USAF has authorized each communications organization to maintain its own file of communications publications. The file will include appropriate Department of the Army, United States Air Force, and commercial publications, in addition to command directives which apply to communications functions, equipment, and procedures of each AF organization. In general, the communications section will contain only that material which is closely related to its function. The responsibility for the basic selection, organization, and control of Communications Publications Files is a function of the major command involved. This responsibility may be delegated to the echelon of command immediately responsible to a major command but may not be further delegated.

The Communications Publication File is organized, administered, and maintained by the unit communications officer in acordance with the directives of the higher headquarters. An index is maintained and an inventory is made of this file every three months.

Itemized below is a general source list of publications to be found in a Communications Publications File:

Combined Communications Board Publications
Commercial Equipment Handbooks
DA Adjutant Letters
DA Catalogs (Signal Corps)
DA Circulars
DA Field Manuals
DA Lubrication Orders
DA Modification Work Orders
DA Pamphlets
DA Regulations
DA Supply Bulletins
DA Technical Bulletins
DA Technical Manuals
DA Training Circulars
Joint Army-Navy-Air Force Publications
Tables of Allowances
Tables of Organization and Equipment
USAF Confidential Orders
USAF Letters
USAF Manuals
USAF Material and Service Directives
USAF Regulations
USAF Stock Lists
USAF Technical Orders
USAF Training Standards

Frequent use of these many and varied references, together with the publications of the intermediate echelons, guide and direct the communications officer in the performance of his duties.

The contents of the different types of publications will be briefly described in the next paragraphs. Space limitations preclude a detailed discussion; consequently the future officer will be required to become more fully acquainted with them at the time he enters active duty. The publications may be divided into three classes for the purpose of this text: Department of the Army Publications, United States Air Force publications, and publications of other agencies.

Department of the Army Publications

Field Manuals (FM). Field Manuals constitute the primary means of promulgating the basic doctrines of military training and operations. They contain training instructions relative to tactics and techniques.

Technical Manuals (TM). Technical Manuals supplement Field Manuals, and cover subjects the separate treatment of which is considered essential to a full accomplishment of the training prescribed in the Field Manuals. They include manuals describing equipment and contain instructions for operation, care, and handling; guidebooks for instructors and specialists; material for extension courses; reference books; administrative materials; and similar specialized subject matter.

Technical Bulletins (TB). Technical Bulletins prepared by technical services disseminate new instructions and information pertaining to technical matters, concerning equipment procured and issued by the preparing agency, or to professional techniques, over which the preparing agency has exclusive jurisdiction. This medium is sometimes used to publish, without delay, technical material that may later be incorporated in manuals or changes to manuals. Technical Bulletins do not contain material pertaining to tactical training or tactical operations.

Supply Bulletins (SB). Supply Bulletins disseminate instructions and information on supply matters such as requisitions and issue, warehouse and depot administration and procedure, safety information, storage packing, marking, and shipping.

Modification Work Orders (MWO). Department of the Army Modification Work Orders provide authentic and uniform instructions for the alteration and modification of United States Army material. The abbreviated designation of the technical service preparing each Modification Work Order is incorporated in the number. For example, MWO ORD A37-W-15; MWO QM 1; MWO SIG 11-447-1. Modification Work Orders follow a standardized form detailing, in successive paragraphs, the major items affected; part modified; purpose of modification; drawings required to apply modification; special tools, test equipment, jigs, and fixtures; special instructions; and remarks.

Tables of Organization and Equipment (T O&E). These tables are published by both the Department of the Army and the Department of the Air Force. They prescribe the organic structure and equipment of military units, the organization, strength, and functions of which are not subject to frequent change. Each T O&E applies to one type of unit which is specified in a descriptive title and designation. Each T O&E is composed of three major sections. The first, **General**, includes a statement of the function, assignment, and capabilities of the organization. The other two, both in tabular form, are **Organization** and **Equipment**. The organization section prescribes the authorized number, grades and qualifications of personnel, and also shows, for information, the number and distribution of weapons, facilities for transportation, and principal items of equipment listed therein. Active units must maintain in their possession all authorized equipment unless otherwise directed by competent authority. The equipment section does not prescribe allowances of equipment required for temporary or special purposes, such as items of clothing and individual equipment; these items are provided for in the Table of Clothing and Individual Equipments. It does not provide items for which allowances are already prescribed in the supply catalogs of the various technical services; nor does it make provision for miscellaneous items including components parts, spare parts, accessories, and expendable items.

Tables of Allowances (T/A). These tables prescribe allowances of equipment authorized for posts, camps, bases, and stations, general and special schools, United States Military Academy, training centers, disciplinary and miscellaneous units or activities, auxiliaries, and overseas departments, bases, and theaters. Auxiliaries, as the term is used above, include activities of a military character which are supervised by the Department of the Army or for which the issue of equipment is authorized by law under regulations prescribed by the Secretary of Defense. Equipment authorized for issue to units by Tables of Allowances is in addition to that authorized in Tables of Organization and Equipment. Such additional equipment will not be taken with a unit into the field or on change of station unless specifically authorized by competent authority (usually indicated in the "basis of issue and remarks" column of the table). In addition to prescribing allowance of equipment for training, school, and all other units and installations whose personnel is provided by allotment, Tables of Allowances also prescribe allowances of training equipment for TO&E units.

A single table, subdivided according to technical services, is published for all items of equipment which are normally required and issued for use at posts, camps, bases, and stations, including training equipment, and which are not taken by units upon change of station. Special equipment for posts, camps, bases, and stations of the United States Air Force is covered in notes appended to the table.

Catalogs (Cat.). Catalogs contain information and instructions on the procurement, storage, issue, requisition, maintenance, and use of equipment and supplies furnished by the technical services. They are the official basis of issue for spare parts, tools, etc. They supplement Tables of Organization and Equipment and Tables of Allowances, and present authorized allowances and initial issues not shown in such tables. Catalogs are divided into sections, one for each technical service. These sections in turn are published in parallel sections having a similar purpose or content. Each such section bears the abbreviated designation of the initiating technical service (SIG, ENG, MED, etc.) followed by a basic number which identifies the content of the section (e.g., SIG 5, ENG 2, MED 3). A complete description and explanation of the catalog system of each technical service may be found in the respective section I pamphlets.

The Department of the Army, Signal Supply Catalog. The Department of the Army, Signal Supply Catalog consists of the following sections:

a) **SIG 1 and 2. Introduction and Index.** Section I, Introduction, explains the purpose and use of each section of the Signal Supply Catalog. It contains an explanation of symbols and abbreviation. Section II, Index, lists all available sections and pamphlets in the Signal Supply Catalog system. This section also indexes, alphabetically by nomenclature and type number, equipments listed in SIG 6, SIG 7, SIG 8 and SIG 10 pamphlets. Hence, it can be used to find any pamphlet in the above series if the user knows the type number or nomenclature of the equipment involved.

b) **SIG 3. List of Items for Troop Issue.** This publication lists alphabetically by nomenclature all type-numbered items which appear on Tables of Equipment (T E's) and Tables of Organization and Equipment (TO &E's) or similar tables. Items are cross-indexed by type number to find nomenclature. SIG 3 is published primarily for the use of unit commanders.

c) **SIG 4-1.** SIG 4-1 lists, as the title indicates, **Allowances of Expendable Supplies for Tactical Organizations**, and **SIG 4-2** lists **Allowances of Expendable Supplies for Schools, Training Centers, Boards, and Fixed Installations.**

d) **SIG 5. Stock List of All Items.** SIG 5 lists, in stock number sequence, all items of Signal Corps equipment to which stock numbers have been assigned. It furnishes stock numbers, nomenclature, complete description, unit of measure, shipping weight and volume, and expendability of each item included. SIG 5 is designed primarily for the use of depots, procurement agencies, and higher echelons. SIG 5 is not a basis of issue. There are four indexes to SIG 5 to assist in locating a stock number when only part of the description is known:

(1) **SIG 5-1. Index by Type Numbers to SIG 5 Stock List of all Items.** An index to all type numbered items in SIG 5.

(2) **SIG 5-2. Index by Manufacturers' Numbers to SIG 5 Stock List of All Items.** Cross-references manufacturer's number to item name and stock number.

(3) **SIG 5-3. Index to SIG 5, Alphabetical Listing of Signal Corps Equipment.** Alphabetical listing of items in SIG 5. A description of the item is cross-referenced to its stock number.

(4) **SIG 5-4. List of Interchangeable and Substitute Items in SIG 5 Stock List of all Items.** A list of items from SIG 5, in stock number sequence, cross-referenced to the stock number of the substitute item.

(5) **SIG 5-5. Pricing Guide for Signal Corps Equipment. Compiled in stock number** sequence and gives unit of measure and unit of cost.

e) **SIG 6. Sets of Equipment.** A series of pamphlets listing component parts of tool sets, test equipment sets, maintenance equipment sets, and similar assemblies. Ordinarily, one pamphlet is furnished for each set.

f) **SIG 7. Organizational Spare Parts.** This consists of a series of pamphlets, each of which lists the organizational spare parts allowances for a major item or major component common to several major items. SIG 7 is currently combined with SIG 8.

g) **SIG 8. Higher Echelon Spare Parts.** This consists of a series of pamphlets similar to SIG 7. Each pamphlet lists guide quantities for initial issue of spare parts to higher echelons of maintenance, army and base depots. SIG 7 and SIG 8 are currently combined in one book, called SIG 7 and 8.

h) **SIG 9. List of Service Parts.** (Not yet published.)

i) **SIG 10. Fixed Plant Maintenance List.** This consists of a series of pamphlets, each of which provides a list of maintenance parts for an individual item or group of items of

fixed-plant equipment. These pamphlets list authorized allowances for station stock and guide quantities for the initial issue of spare parts for field and base depot stock for fixed-plant maintenance.

j) **SIG 10-2.** The full title of this publication is: **Fixed Plant Maintenance Lists Factor Table, Manufacturer's Code Number List, Abbreviations.** SIG 10-2 contains a factor table to be used to determine the quantities of parts to be stocked at stations and to be used as a guide in making initial issues to supply depots where three or more units of a given type of equipment are maintained.

k) **SIG 10-3. Equipment for Which Fixed Plant Maintenance Lists Will Not be Furnished.**

l) **SIG 11-1. Parts Control Lists, Procurement and Issue Control Lists.** A compilation of Procurement and Issue Control lists on Signal Corps Equipment.

m) **SIG 11-2. Parts Control Lists, Component Applications Lists on Type-Numbered Items.** A list of type-numbered components and the sets or equipment in which the component is used, together with the number of times the component is used in each equipment. Components are listed in sequence by type number.

n) **SIG 11-3. Parts Control Lists, Components Applications Lists on Nontype Numbered Items and Substitution Information.** SIG 11-3 is divided into two sections; one section is a list of nontype numbered components and the sets or equipments in which the component is used, together with the number of times the component is used in each equipment; the second section lists the permissible substitute items for sets of equipments and components. Nontype-numbered components are listed in sequence by alphabetic description.

U. S. Air Force Publications

AF Regulations. AF Regulations are the primary administrative regulations for the government of the Air Force. They contain USAF policies, directives, and or instructions of a permanent nature which are of general application to all USAF activities under the command and control of the Commanding General, USAF, or which may be of application to specific USAF activities but where general distribution is necessary. These regulations are printed on standard lettersize (8" x 10½") paper and receive a wide distribution among all activities of the USAF in the United States and overseas. The title of each regulation consists of two parts; the subject classification or general title, and the subtitle naming the specific matter covered in the publication. Thus, an AF Regulation dealing with the subject of communications will bear the general title **COMMUNICATIONS.** The subtitle will cover the specific subject; for instance, **Fixed Communications Systems and Facilities,** or **Communications Publications File.**

The system of numbering used for AF Regulations is also used for AF Letters, AF Materiel and Service Directives, and AF Training Standards. This system has been adopted as the standard system of numbering administrative publications and is used by all commands and air forces and by all echelons thereunder including posts, stations, or air bases, in the issuance of regulations, memorandums, instructions, or other administrative publications. The number consists of two parts separated by a dash. The first part is the number of the subject classification or general title and is known as the "base number." The second part is the number assigned to the subtitle and is known as the "subnumber." Subnumbers within each base number run consecutively. AF Regulation 5-1, General Index of AF Standard Publications, establishes a basic index and numbering system for Air Force standard publications (AF Regulations, AF Letters, and AF Manuals) which are given base numbers indicating general subjects. The base numbers pertaining to communications and electronics are:

Base No. 100 Communications
Base No. 101 Electronic Systems
Base No. 102 Communications Systems

AF Letters. AF Regulation 5-1 serves as the general index by which AF Letters are classified and numbered. The title is in the form of a military or **Subject and To** letter, the subject describing the content of the publication. A numerical index of AF Letters, listing all of the publications currently in force, is published quarterly as AF Letter 5-2. A separate series of publications exists in the form of unnumbered letters. Unnumbered letters are used for announcements or instructions which require only one-time action or are purely informative in nature.

AF Training Standards. These publications set forth the standards of proficiency for the training of units and individuals. Whereas the numbering system is the same as that for AF Regulations and AF Letters, the subject classification corresponding to the base numbers differs widely from AF Regulation 5-1. AF Training Standard No. 0-1 sets forth the general index system of base numbers and corresponding subject classification for these publications. AF Training Standard No. 0-2, published quarterly, is the numerical index of all AF Training Standards currently in force.

AF Manuals. AF Manuals are a medium for publishing a compilation of material for the purpose of simplifying the presentation and understanding of diverse matters relating to a single subject, procedure or responsibility. They are titled, numbered, and indexed as prescribed in AF Regulation 5-5, and 5-1.

AF Materiel and Services Directives (M&S Directives). Published by the Commanding General, Air Materiel Command, in the name of the Chief of Staff, United States Air Force, these publications establish specific operating procedures and instructions for procurement; and operating instructions in materiel and service fields other than supply agencies within the USAF. The numbering system is the same as that used for AF Regulations. M&S Directive No. 5-1 sets forth the base numbers and general subject classifications which are given to AFM&S Directives. This general index, with minor changes and additions, is substantially in accord with AF Regulation 5-1, General Index of AF Administrative Publications. A numerical index of M&S Directives, listing all of these publications currently in force, is published quarterly as M&S Directive No. 5-2.

AF Technical Orders (T.O.). Published by the Commanding General, Air Materiel Command, in the name of the Chief of Staff, USAF, these publications disseminate specific technical directives and information on AF equipment with respect to the inspection, storage, operation, modification, and maintenance of such equipment, and prescribe items of equipment to be assembled in kits or sets. In general, Technical Orders are published in looseleaf form, letter-size, with the left-hand margin punched for filing. Thus the files of technical directives and associated data may be consolidated in numerical sequence. Further, all technical instructions and information relating to individual airplanes, engines and other items of equipment may be assembled in individual binders for the convenience of personnel whose duties require that they constantly refer to such material. Many of these publications are Technical Order Handbooks dealing with the operation or maintenance of specific items of equipment or with more general subjects, for example, T.O. No. AN 16-30-ARC 3-2 "Handbook of Operating Instructions for Radio Set AN/ARC-3," T.O. No. 30-20F-2 "Basic Radio Maintenance Trailing Guide," or, T.O. No. 16-1-2 "Flying with Radar."

In addition to the classification incident to the numbering system, explained below, Technical Orders are classified as to security and as to urgency. The security classifications used are **RESTRICTED** and **CONFIDENTIAL**, most are unclassified. Publications classified as CONFIDENTIAL are separately indexed and filed. As to urgency, Technical Orders (other than handbooks) are, broadly speaking, classified as Urgent or Routine. Urgent Technical Orders have a red cross border (X), a red diagonal border ( ) or the words "Immediate Attention," printed in red letters, at the top and bottom of each page. Routine Technical Orders are printed on plain white paper. Technical Orders, according to their urgency are classified as follows:

Immediate Action Technical Orders. Technical Orders specifying "work to be accomplished immediately" denote dangerous conditions which require grounding of the

aircraft pending compliance wi[illegible] e Technical Order. This class of Technical Orders is printed on white paper with a border of red "X"s. The red "X"s, in addition to providing a distinctive identification, correspond to the symbol (red "X" or red cross) used on the Maintenance Inspection Record for Airplanes (AF Form 41B) to indicate a defect or unsatisfactory condition of such a nature that it renders the aircraft unsafe for flight.

Immediate Attention Technical Orders. Technical Orders containing special operations, informative, precautionary, or restrictive instructions which vitally affect the safety of flight, operation, and use, or combat effectiveness, but requiring no work or inspections (other than placarding or marking of flight instruments, when specified) and therefore involving no grounding of aircraft, are printed on white paper with the words **Immediate Attention** in red letters at the top and bottom of each page. This class is also used for important modification or inspection instructions, which would normally require **Immediate Action** classification bear no **grounding** significance when applied to such equipment.

As soon as Possible Technical Orders. Technical Orders specifying "work to be accomplished as soon as possible and not later than the next .... inspection period" normally denote correction of defects affecting the flying or combat efficiency of aircraft which are not so urgent or dangerous as to require grounding of aircraft. This class of Technical Orders is printed on white paper with a border of red diagonals ( ). The red diagonals in addition to providing a distinctive identification correspond to the symbol ( ), used on the maintenance inspection records for airplanes to indicate a defect or unsatisfactory condition not sufficiently serious to render the aircraft unsafe or unfit for flight, but of such a nature that it must be corrected before the aircraft can be considered to be in first class mechanical condition.

Routine Technical Orders. This class of Technical Orders is printed on plain white paper. The following types of Technical Orders are included in this classification.

Technical Orders specifying "work to be done as soon as practicable," are those which can be accomplished within broader time limits, that is, whenever accomplishment will not interfere with flying schedules unless local conditions necessitate more urgent action, or when aircraft or equipment are in the depots and bases undergoing repairs or major overhaul. These Technical Orders normally denote conditions which are not necessarily serious, but which are essential to provide remedial action and to make sure that the required repairs will be made so as to forestall possible malfunctioning of equipment or failure of materials.

Technical Orders which provide **instructions for modification of equipment**, or installation of special equipment on selected aircraft, or equipment for the performance of special duties or missions, do not normally specify when the work is to be performed. Such special installations or modifications are not normally made to all equipment of the same model or series, and compliance is effected only upon issuance of additional instructions directing the work to be accomplished on equipment bearing specific serial numbers. Technical Orders of this nature contain a notation stating that the work will be accomplished "if necessary, when, and as directed by the Commanding General, Air Materiel Command."

The title of each Technical Order consists of three parts; namely, **the general title, the group title,** and **the subject title**.

The **general title** is that of the general AF property class of the equipment to which the Technical Order pertains.

The **group title** is a further natural grouping of related subjects under the general class.

The **subject title** indicates as precisely as possible the nature of the contents and the particular equipment or part to which the order pertains. As a complete example, the title for T.O. No. 16-5-53 would be "Communications Equipment" (General title), "Aircraft Radio" (Group title), and "Radio Compass SCR-269-( )-Resealing of Loops and Maintenance of Dehydrators" (Subject).

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Technical Orders are assigned numbers consisting of two or more parts separated by dashes. The numbers serve for identification, indexing, and filing. The first part of the number normally corresponds to the number of the AF property class covered. Thus, the number "16" is the first part of the number of all Technical Orders pertaining to Communications Equipment, AF property class 16. The "( )" series is established for indexes, for orders pertaining to the subject of publications, and for miscellaneous instructions that cannot be otherwise classified. The second part is a number assigned to identify all the Technical Orders pertaining to a particular subdivision (type, model, etc.) of the general property class covered. This second part of the number corresponds to the **group title** mentioned above. The third part consists of numbering in series, beginning with the number "1" in the order of issue, the individual Technical Orders of each subdivision of a general property class, a separate series of numbers being used for each subdivision.

A "Numerical Index of Technical Publications," published in loose-leaf form as T.O. 00-1, is reissued on 1 February of each year and at intervals during the ensuing twelve-month period. In addition, cumulative supplements to T.O. 00-1 are issued every two weeks.

The importance of Technical Orders as directive and informative media cannot be overemphasized. All USAF personnel must have a general understanding of the Technical Order System. Further, those concerned directly with the operation, maintenance, or inspection of USAF equipment must be conversant with the contents of each technical publication pertaining to that equipment. More complete information on these publications is contained in T.O. 00-5-1 "General Provisions—Explanation of Technical Order and Stock List System," and in T.O. 00-5-2 "Distribution of Technical Publications."

Stock Lists. Stock Lists are the official published item identification lists, arranged by property class, of active items of USAF equipment, supplies, and spare parts which the SAF stores and issues. Stock lists constitute the official media for directing the accomplishment of item identification changes by field supply and maintenance installations, and the official reference for classification and requisitioning information, and for establishing, maintaining, and reporting stock record data. Stock lists contain part numbers, standardized nomenclature, regulated item information, classification as to status in accordance with the provisions of AR 850-25, unit of issue, unit cost, and stock numbers of USAF property that is either in stock or being procured. Application of items, source of procurement, action directive phrases, authorization for local manufacture or local purchase, etc., is also included when applicable. In addition, illustrations and other pertinent information are included in Stock Lists of certain classes.

Dead Item Stock Lists are the official publications, arranged by property class, listing items of USAF property for which disposal action has been determined, and which serves as directions to field supply and maintenance activities for accomplishment of such action.

The **Part Number Index** is a numerical listing of part numbered items of USAF property indicating property classification to serve as a guide to Stock Lists and Dead Item Stock Lists.

Stock Lists are assigned basic numbers consisting of the AF property class symbol preceded by the letter "S" to avoid conflict with Technical Orders. Thus, the basic number of the Stock List for Class 16-A property, "Airborne Communication and Test Equipment," is "S-16-A." Dead Item Stock Lists are distinguished from the stock list (active) by suffixing the word "dead" to the basic number, e.g., "S-16A Dead." Part number Indexes are numbered "S-00-1."

Stock Lists, like Technical Orders, are filed in numerical sequence as listed in T.O. 00-1, "Numerical Index of Technical Publications," which includes an index of Stock Lists.

Publications of Other Agencies

Combined Communications Board Publications (CCBP). These publications are numbered pamphlets compiled by the Combined Communications Board, establishing operating procedures for combined use. (Definition of "Combined": Among all of the services of one nation and all the services of another nation, but not necessarily within a particular service of either nation or between the services of either nation.) CCBP-7 "Combined Communication Instructions" explains these publications in greater detail.

Joint Army-Navy-Air Force Publications (JANAP). These publications are numbered pamphlets compiled by the Joint Communications Board for joint use. (Definition of "Joint": Among all of the services of one nation, but necessarily within the services of that nation.) This series has been adopted as the medium for publishing a compilation of **Joint Communications Instructions** containing all existing agreements and such further agreement with respect to communications procedures as may be necessary to eliminate differences in Army, Navy, and Air Force.

3. USAF PROPERTY CLASSES

The USAF, as well as the Technical Services of the Army, subdivides its supplies into property classes for convenience of administration. There are approximately thirty USAF property classes. Each of these main classes are further subdivided into subclasses in order to group items of similar characteristics. AF Manual 67-1 is the basic supply publication.

Class 16—Communications Equipment

The communication officer should understand the general scheme of the AF property system and know the setup of class 16 property thoroughly, since the major portion of his supplies will be found in this class.

AF Property Class 16 consists of all items of radar and communications equipment, accessories and parts, which are stored and issued by the USAF. Class 16 is intended to include communications equipment peculiar to (i.e., used exclusively by, or of primary interest to) the USAF and all components and associated items of this equipment, even though some of these components and associated items may also be used in equipments not peculiar to the USAF. Accordingly, Class 16 supplies properly fall within the general category of AF supplies. Consequently, communications supplies which properly fall within the general category of Common Supplies are not normally listed in Class 16 Stock Lists. Such common items of communications supplies are procured, stored, and normally issued by the Signal Corps and are listed in the Department of the Army Signal Supply Catalog; hence, they are items of Signal Corps Property rather than USAF Property.

An appreciable number of common items, however, are included in AF Property Class 16 by virtue of the necessity for including all components, accessories, maintenance parts, and associated items of major equipments. Such components, accessories, and maintenance parts are often widely employed in communications equipments generally, as well as in those equipments peculiar to the USAF. Thus, a certain ground radio set may be used exclusively by Air Force Units; however, the transmitter or the receiver of that set may be used in one or several other sets which are used extensively by ground units of the Army. Many items of test equipment included are likewise employed generally, as are also many of the maintenance parts such as vacuum tubes, condensers, resistors, etc.

AF Property Class 16 is subdivided into six lettered subclasses as follows:

16-A Airborne Communications Equipment. This subclass includes all airborne communications equipment such as radar, radio, and countermeasures. Test equipments are also stocked in this subclass. Examples of included equipments are: electronic altimeters, communications countermeasures equipment, radio compasses, frequency meters, airborne radio sets, and test sets including special purpose test sets for airborne communications equipment and test sets whose general purpose application is restricted to airborne and ground communications equipment.

16-B Ground Radio Equipment. This subclass includes all ground, radio and navigational aids equipment peculiar to the United States Air Force, except ground radar. Examples are: ground radio navigational aids such as radio homing beacons and radio ranges, antenna systems, VHF fighter control systems, and other ground radio sets peculiar to the USAF. This class does not include those many ground radio sets used for general communications purposes by both the Army and Air Force. Because of such general usage, most of the Army radio sets are common supplies; therefore, they are not listed in Class 16; but are listed in the Department of the Army Signal Supply Catalog.

16-C Ground Radar Equipment. This subclass includes all ground radar sets and components, associated modification and improvement kits, and ground radar special test sets. Ground radar equipment includes aircraft warning sets, radar beacons, and other navigational aids such as GCA (Ground Controlled Approach), radar countermeasures equipment, ground interrogators for identification equipment, and other ground radar sets peculiar to the USAF. Note that this subclass, like 16-B, includes only ground components or equipments. Class 16-A, as noted before, includes the airborne sets and components.

16-D AF Installation Parts for Radar and Communications Equipment. This subclass includes all special purpose airborne-installation parts for radar and communications equipment whether or not designed for application to a specific aircraft. There are the installation parts for 16-A equipments: the various brackets, channels, plates, supports, etc., for mounting receivers, transmitters, dynamotors and other communications components used in airplanes. Also included are radomes and their retracting mechanisms, and chaff dispensers.

16-E Radio and Radar Maintenance Parts. This subclass includes all special purpose maintenance parts for equipment classified in subclasses 16-A, 16-B, and 16-C, as well as those general purpose items whose predominant USAF usage is for maintenance of radar and communications equipment. Examples of materials listed in this subclass are: bulk cable and wire (other than general purpose) capacitors, plugs, relays peculiar to radio and radar equipment, resistors, electronic tubes, transformers, and so forth.

16-F Radio Crystals. This subclass includes all types of quartz crystals for radio communications equipment.

4. COMMUNICATION INSPECTION AND MAINTENANCE

It is essential to successful Air Force operations that the communications system operate at peak efficiency at all times. In order for this to be acomplished, it is necessary that each communication officer operate an effective system of technical inspection and maintenance so that equipment failure may be reduced to a minimum.

There are only two kinds of equipment, two kinds of maintenance, two kinds of technical administration: **good** and **bad.** The purpose of inspection is to insure the **good** outweights the **bad** by a margin commensurate with the high ideals of the USAF mission.

Responsibility

Inspection is a command function. Commanders of each and every echelon of command are charged with the creation and maintenance of an efficient inspection system which will operate to assist materially in the discharge of such responsibility. Inspection, concerned primarily, as it is, with maintaining a high standard of efficiency, enables the command officer to ascertain the extent to which orders are enforced and is a means whereby the state of efficiency of commands may be determined. The mere creation and carrying on of an inspection system does not relieve a commanding officer of his responsibility for accomplishing efficient employment of men and materials. It is, however, an essential aid to the proper discharge of that duty.

Unit Supervision. Inspection is continuous. In an informal sense, it begins with the operator, or the person using the equipment or handling the material. He will consider this a portion of his duty rather than an inspection. Likewise, the section chief, in exercising his supervision of the operators and technicians in his section, conduct daily or weekly checks upon the performance of their operation and upkeep of the equipment used. The weekly inspection tours of the unit commanding officer are further examples of supervision within the unit involved. Although check lists probably will be kept, and such inspections are manifestly for the increased efficiency of the unit, they are not, by definition, inspections in the sense applied to the formal inspections made by air inspector personnel.

An inspection is an official examination of a military unit, facility, or activity made in the course of an inspector's prescribed routine to determine and report on the extent and degree of compliance with laws, regulations, orders or other standards, and on the condition of personnel and material.

Organization. Commanders of air forces, independent commands, subordinate commands, groups, air bases, and similar organizations organize under one head all air inspection activities and air inspection personnel assigned to their respective headquarters. The senior inspector is designated the air inspector of the command, subordinate command, group, base or other organization concerned. Adequate personnel qualified to examine, appraise, and report upon the efficiency and economy of administration, services, supply, maintenance, operations, training and other assigned functions of the activity are assigned to the office of the air inspector to conduct inspections. Inspection is the primary duty of such personnel.

Air inspectors and assistant air inspectors selected by commanders are assigned only with the approval of the next higher echelon of command.

Frequent and thorough inspection is imperative in order to maintain full and efficient control and employment of men and material at all times. Although the frequency of inspection is not limited, the following are considered the minimum requirements:

The Air Inspector, Headquarters, USAF, will conduct semiannual inspections of those command headquarters, reporting directly to Headquarters, USAF. One of these will be the annual general inspection. He must also conduct annual inspections of the headquarters of air forces operating outside the continental limits of the United States and of such subordinate echelons as the Chief of Staff, USAF, may deem necessary.

Each echelon below Headquarters, USAF, level down to and including groups, air bases, separate detachments, and comparable units and activities must be given a complete and formal inspection at least semiannually by an air inspector of a higher echelon of command. One of these inspections will be the annual general inspection.

The command of each air force and independent command will require his air inspector to make inspections of a sufficient number of subordinate echelons, including groups, air bases, and similar organizations, to keep informed concerning the efficiency and economy of operations of the command.

Inspection of air bases, operational satellite bases, groups and other comparable operating units by their own inspectors is a continuing process. Such inspections are made to assure coverage of all activities under the command jurisdiction of their respective headquarters at least once each month unless otherwise prescribed by regulations or by the Chief of Staff, United States Air Force.

Whenever practicable, inspections of lower echelons by wings and higher headquarters are made by inspection teams. Teams are composed of the necessary qualified specialists in order to cover adequately every phase of the activity. Air inspectors hold to a minimum any possible interference with the normal activities of the organization being inspected.

Policies. Whenever an inspection has been made, a written report is prepared. Such a report is in the form prescribed by the commander ordering the inspection.

Upon completion of the inspection, the air inspector discusses his findings and the data contained in his report with the commander and staff of the activity examined. In the discussion of matters to be reported upon, the air inspector affords the commander and his staff ample opportunity to present any modifying instructions from higher headquarters or other circumstances which may have a bearing on the statements to be included in the report. Prompt action will be taken by commanders on irregularities and deficiencies reported, both to correct the specific case and to prevent recurrences.

Supply and Maintenance Inspections. AF Regulations direct that supply and maintenance inspections be of such frequency and scope as to insure fulfillment of the broad overall responsibilities of commanding officers. The scope and detail of supply and maintenance inspection include every USAF technical phase or subject, and all subjects covered by technical publications which are pertinent to equipment furnished to, and maintained by the Air Force.

5. UNSATISFACTORY REPORTS

Importance and Use

The **unsatisfactory report** (UR) (AF Form No. 54) is a means whereby individuals in the Air Force may submit through channels reports of unsatisfactory conditions and recommendations to preclude recurrences.

The communications officer is in close touch with both the methods and machines which compose the great ground organization behind the personnel who fly. It should be borne in mind, however, that there is always room for improvement. Information concerning even the smallest failure may be of great value if reported to the proper authority in time. Everyone is encouraged to submit unsatisfactory reports whenever he sees an opportunity to contribute to greater efficiency by suggesting correction of faults.

Forwarding authorities are required by AF regulations to forward all unsatisfactory reports whether or not they concur in the originator's findings and recommendations.

The purpose of the unsatisfactory report system is to aid the Air Materiel Command in accomplishing its task of maintaining all AF equipment in its best operating condition. Unsatisfactory reports are, in effect, field reports on how AF equipment is standing up under the conditions for which it was intended. It is through these reports that AMC is able to bring about improvement in equipment before its delivery to combat areas, and fill in gaps in established maintenance procedures.

Unsatisfactory reports are required to be initiated by any individual assigned or attached to the Air Force upon the first, and all subsequent, observations of any of the unsatisfactory conditions mentioned below. It is extremely important that all failures of equipment be reported immediately. This includes repetitive failures since the number of failures reported often determines the action required. Commanding officers are required to insure that all personnel concerned are advised of the importance and use of these reports and the necessity for their prompt submission whenever any unsatisfactory conditions are described or encountered. It is the responsibility of the officer in charge of the office or activity where the unsatisfactory condition exists to insure prompt submission of an unsatisfactory report as prescribed in T.O. 00-35D-54.

If deemed necessary for expeditious processing of unsatisfactory reports, the base commanding officer may establish a central clearing office under the direction of the base maintenance officer for the supervision, preparation and submission of unsatisfactory reports.

A more specific and detailed study of UR's, their form and application in the field of communication will be considered later.

BIBLIOGRAPHY

The following bibliography, although not intended as definitive, should provide a representative cross section of material available in the field of communications. It is believed that the civilian references, with their supplemental bibliographies, will provide a sufficiently wide variety of references to afford adequate coverage of all subjects examined by this text. The military bibliography has been selected to illustrate the general scope of military publications which are available to the communications officer.

CIVILIAN PUBLICATIONS

Applied Electronics. Staff (Electronic Engineering), Massachusetts Institute of Technology, John Wiley and Sons, Inc., New York, 1943.

Aircraft Radio and Electrical Equipment. 2nd edition, Howard K. Morgan, Pitman Publishing Corporation, New York, 1941.

Aviation Radio. Henry W. Roberts, William Morrow & Company, New York, 1945.

Communication Engineering. William Littell Everitt, McGraw-Hill Book Company, New York, 1937.

Electronic Engineering Master Index. Frank A. Petragliee, The Macmillan Company, New York, 1946.

Electronics Dictionary. Nelson M. Cook and John Markus, McGraw-Hill Book Company, Inc., New York, 1945.

Fields and Waves in Modern Radio. John Wiley and Sons, Inc., New York, 1944.

Principles of Radar. 2nd edition, Staff (Radar School), Massachusetts Institute of Technology, McGraw-Hill Book Company, Inc., New York, 1946.

Radar Engineering. Donald G. Fink, McGraw-Hill Book Company, Inc., New York, 1947.

Radar System Engineering. Louis N. Ridenour, McGraw-Hill Book Company, Inc., New York, 1947.

Radio Engineers' Handbook. Frederick Emmons Terman, McGraw-Hill Book Company, Inc., New York, 1943.

Servomechanism Fundamentals. Henry Lauer, Robert Lesnick, and Leslie E. Matson, McGraw Hill Book Company, Inc., New York, 1947.

Transmission Lines Antennas and Wave Guides. Ronald W. P. King, Harry Rowe Mimno, and Alexander H. Wing, McGraw-Hill Book Company, Inc., New York, 1945.

Ultra-High-Frequency Radio Engineering. W. L. Emery, The Macmillan Company, New York, 1944.

Ultra-High-Frequency Radio Simplified. Milton S. Kiver, D. Van Nostrand Company, Inc., New York, 1945.

Understanding Microwaves. Victor J. Young, John F. Rieler Publisher, Inc., New York, 1946.

MILITARY PUBLICATIONS

Technical Manuals

TM 1-455	Electrical Fundamentals.
TM 1-460	Radio Telephone Procedure.
TM 1-465	Airground Communication.
TM 1-470	Aircraft Radio Shop Practice.
TM 11-223	Signal Equipment Directory, Power Units.
TM 11-227	Signal Communication Equipment Directory, Radio Communications Equipment.
TM 11-233	Radio Set SCR-188-A.
TM 11-243	Radio Set SCR-291-A, (Direction Finding).
TM 11-314	Antennas and Antenna Systems.
TM 11-330	Switchboards BD-71, BD-72, BD-72-A and BD-72-B.
TM 11-332	Telephone Central Office Set TC-4.

TM 11-333 Telephones EE-8, EE-8-A, and EE-8-B.

TM 11-334 Timing and Telephone Set ML-110.

TM 11-335 Telephone Central Set TC-1.

TM 11-338 Telephone Central Set TC-10.

TM 11-341 Telephone Terminal Sets TC-21-A and TC-21-B (Carrier) and Repeater Set TC-23-A (Carrier).

TM 11-342 Ringer Set TC-24 Ringing Equipments EE-100-TI, EE-100-A, and EE-101-A (Voice Frequency).

TM 11-343 Relay Unit BE-84-A (Teletype Trunk).

TM 11-348 Telephone Repeater Set TC-29-A.

TM 11-352 Printer TG-7-A and Teletypewriters TG-7-B and TG-37-B.

TM 11-353 Installation and Maintenance of Telegraph Printer Equipment.

TM 11-354 Telegraph Printer Sets (Teletypewriter) EE-97 and EE-98; Teletypewriter Sets EE-97-A, EE-98-A and EE-102.

TM 11-355 Telegraph Terminal CF-2-A (Carrier).

TM 11-355B Telegraph Terminal Set TC-22-B (Carrier).

TM 11-356 Radio Teletype Terminal Equipment AN FGC-1 or AN FGC-IX.

TM 11-358 Telegraph Central Office Set TC-3 and Switchboard BD-100.

TM 11-363 Pole Line Construction.

TM 11-368 Tactical Open Wire Line Construction.

TM 11-369 Spiral Four Cable.

TM 11-375B Facsimile Equipment RC-120, RC-120-A and RC-120-B and Facsimile Set AN TXC-1.

TM 11-377 Boemhe Automatic Keying and Recording Equipment.

TM 11-438 Operations Center AN TTQ-1. Portable Filter and Operations Room Unit Assembly.

TM 11-448 Operations Center AN TTQ-2.

TM 11-454 The Radio Operator.

TM 11-455 Radio Fundamentals.

TM 11-457 Local Battery Telephone Equipment.

TM 11-458 Common Battery Telephone Equipment.

TM 11-464 The Teletypewriter Operator.

TM 11-466 Radar Electronic Fundamentals.

TM 11-467 Radar System Fundamentals.

TM 11-471 Manual Telephone Central Office Installation.

TM 11-473 Central Office Maintenance.

TM 11-474 Telephone Substation Installation.

TM 11-475 Principles of Long Distance Telephone and Telegraph Transmission.

TM 11-476 Radio Direction Finding.

TM 11-483 Suppression of Radio Noises.

TM 11-484 Elementary Military Cryptography.

TM 11-485 Advanced Military Cryptography.

TM 11-486 Electrical Communication Systems Engineering.

TM 11-487 Electrical Communications Systems Equipment.

TM 11-488 Remote Control Equipments for Ground Radio Sets and Interconnections with Wire Systems.

TM 11-498 Fundamentals of Telephony and Manual Telegraphy.

TM 11-626 Radio Set AN TRC-5 (XC-3).

TM 11-632 Radio Set AN TRC-6 (XC-2), Description and Installation.

TM 11-633 Radio Set AN TRC-6 (XC-2), Preventive Maintenance and Auxiliary Equipment.

TM 11-680 Teletypewriter Circuits and Equipment (Fundamentals).

TM 11-755 Grounds, Grounding Procedure, and Protective Devices for Wire Communication Equipment.

TM 11-2001 Complete 100-mile Spiral-Four Carrier System.

TM 11-2003 Carrier Hybrid CF-7.

TM 11-2008 Converter Set TC-33 (Carrier, 2-Wire 4-Wire) and Repeater Set TC-37 (Carrier 2-Wire).

TM 11-2009 Telegraph Terminal CF-6 (Carrier).

TM 11-2201 Reperforator Teletypewriter Set TC-16 and TC-17.

TM 11-2207 The Radioteletype Code Room and Signal Center, Installation Procedure and Maintenance Guide.

TM 24-205 Administrative Procedures for Communication Services.

Technical Orders

TO 00-1-1

TO 00-5-1

TO 00-5-2

TO 16-1-01

Field Manuals

FM 1-45 Signal Communication.

FM 1-46 Fighter Radiotelephone Procedures and code.

FM 1-75 Combat Orders.

FM 11-5 Mission, Functions and Signal Communications in General.

FM 24-8 Combined Teletypewriter (Teleprinter) Procedure.

FM 24-10 Combined Radiotelegraph (W T) Procedure.

FM 24-16 Signal Orders, Records and Reports.

FM 24-17 Signal Center and Message Center Procedure.

FM 24-18 Radio Communication.

FM 24-20 Field Wire Techniques.

FM 24-22 Combined Visual Signaling (V S Procedure).

FM 24-75 Telephone Switchboard Operating Procedure.

FM 100-20 Command and Employment of Air Power.

FM 101-5 Staff and Combat Orders.

APPENDIX

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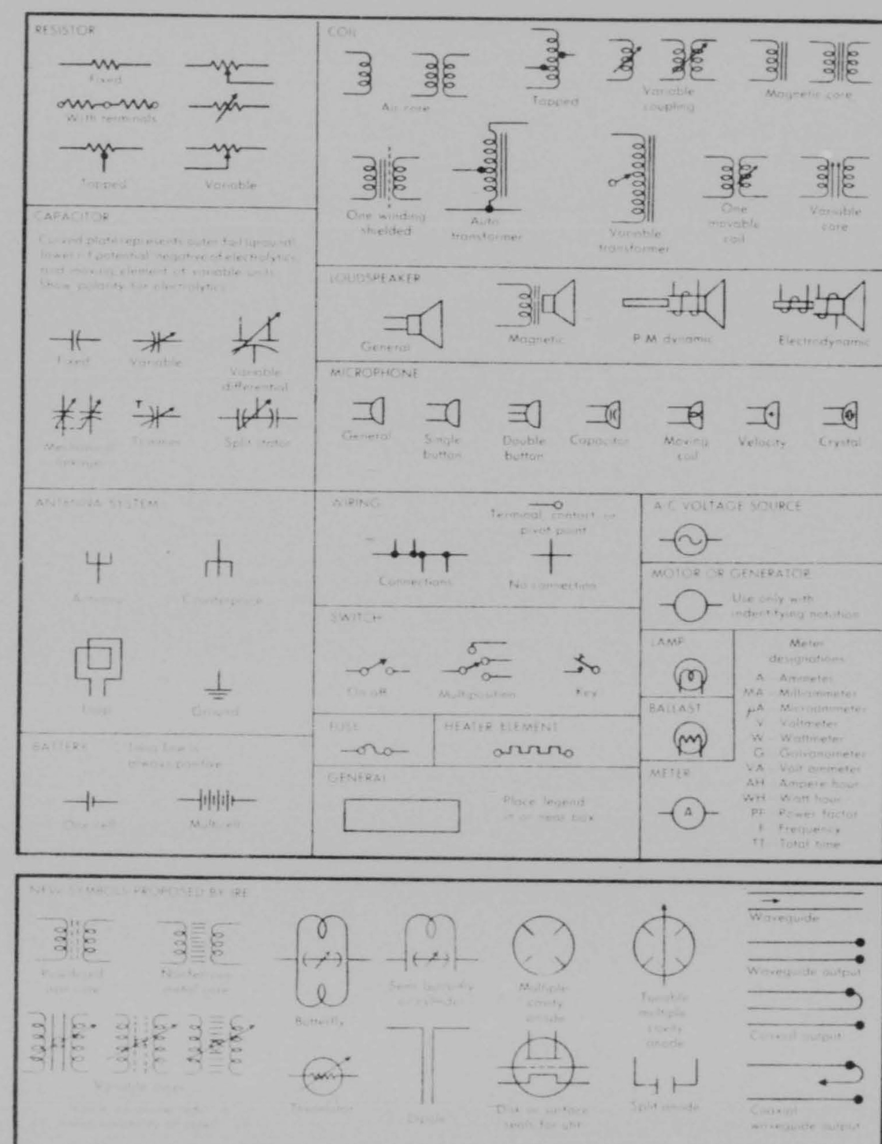

ELECTRONIC SYMBOLS

1. D-c Circuits

a. OHM'S LAW.

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}} \quad \left(I = \frac{E}{R}\right)$$

$$\text{Volts} = \text{Amperes} \times \text{ohms} \quad (E = I \times R)$$

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}} \quad \left(R = \frac{E}{I}\right)$$

b. POWER

$$\text{Watts} = \text{Volts} \times \text{amperes} \quad (P = E \times I)$$

c. RESISTANCE IN SERIES.

$$R_{TOTAL} = R_1 + R_2 + R_3 + \ldots$$

d. RESISTANCES IN PARALLEL.

$$\frac{1}{R_{EQUIV}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \ldots$$

or:

$$R_{EQUIV} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \ldots}$$

e. TWO RESISTORS IN PARALLEL.

$$R_{EQUIV} = \frac{R_1 \times R_2}{R_1 + R_2}$$

2. A-c Circuits

a. CURRENT, VOLTAGE, IMPEDANCE.

$$E = I \times Z;\ I = \frac{E}{Z};\ Z = \frac{E}{I}$$

b. INDUCTIVE REACTANCE.

$$X_L \text{ (ohms)} = 2\pi fL$$

c. CAPACITIVE REACTANCE.

$$X_C \text{ (ohms)} = \frac{1}{2\pi fC}$$

d. IMPEDANCE.

$$Z \text{ (ohms)} = \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$$

e. INDUCTORS IN SERIES.

$$L_{TOTAL} = L_1 + L_2 + L_3 + \ldots$$

f. INDUCTORS IN PARALLEL.

$$L_{EQUIV} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots}$$

g. CAPACITORS IN SERIES.

$$C_{EQUIV} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots}$$

h. CAPACITORS IN PARALLEL.

$$C_{TOTAL} = C_1 + C_2 + C_3 + \ldots$$

i. CONDITION OF RESONANCE.

$$X_L = X_C$$

$$2\pi fL = \frac{1}{2\pi fC}$$

j. RESONANT FREQUENCY OF A TUNED CIRCUIT.

$$f \text{ (cps)} = \frac{1}{2\pi\sqrt{LC}}$$

3. Radio Frequency

Frequency and wavelength relations:

$$\text{Wavelength (in meters)} = \frac{300{,}000{,}000}{\text{Frequency (in cycles)}}$$

$$\text{Frequency (in cycles)} = \frac{300{,}000{,}000}{\text{Wavelength (in meters)}}$$

4. Horizon Distance (optical line-of-sight)

a. Horizon distance can be calculated from the formula:

$$S = 1.42\sqrt{H}$$

where S is the distance in miles and H is the height of the observer's eyes in feet.

b. The table which follows gives the horizon distance for various heights of antenna above ground level.

Height of antenna above ground (feet)	[illegible]
5	3.2
20	6.4
50	10.0
100	14.2
500	32.0
1,000	45.0
2,000	63.5
3,000	78.0
5,000	100.0

5. Horizon Distance (radio line of sight)

a. $D = \sqrt{2h} + \sqrt{2H}$

where D = total distance in miles between transmitting and receiving antennas

h = height of transmitting antenna in feet

H = height of receiving antenna in feet.

SUMMARY OF FORMULAS

EXAMPLE OF AN NOMENCLATURE FOR A COMPLETE SET- RADIO SET *AN/ARC-6A

*AN COMPLETE SET	/	A AIRBORNE	R RADIO	C COMMUNICATION	—	6	A
ARMY-NAVY	SLANT	INDICATOR LETTERS		INDICATOR LETTERS		NUMBER	MODIFICATION LETTER

ARMY-NAVY

Indicating nomenclature is being applied to a complete set - not a component.

*UNITED NATIONS STANDARDIZATION.

A star,*, used as a prefix to a type number identifies the item as having been standardized by the Army or Navy and another United Nation.

SLANT

Assigned no meaning when preceded by AN.

INDICATOR LETTERS

INSTALLATION

A—airborne (installed & operated in aircraft)

C—air transportable (designed to be transportable as stated in specification or military characteristics)

F—ground, fixed

G—ground, general ground use (includes) two or more ground installations)

M—ground, mobile (installed as operating unit in a vehicle which has no function other than transporting the equipment)

P—ground, pack or portable (horse or man)

S—shipboard

V—ground, vehicular (installed in vehicle designed for functions other than carrying radio equipment, etc., such as tanks)

T—ground, transportable

U—general utility (includes two or more general installation classes, airborne, shipboard and ground)

TYPE OF EQUIPMENT

B—pigeon

C—carrier (wire)

F—photographic

G—telegraph or telephone (wire)

I—interphone and public address

M—meteorological

N—sound

P—radar

R—radio

S—special types (heat, magnetic, etc.) or combination of types

T—telephone (wire)

V—visual and light

X—facsimile or television

EXAMPLES OF AN TYPE NUMBERS

Type Number	Indicates
AN/ARC-3	Airborne radio communications set No. 3.
**AN/ARR-4*	Airborne radio receiving set No. 4, standardized by the Army or Navy and another United Nation.
AN/CRT-7 (XA-1)	Aircraft Radio Laboratory developmental model No. 1 of air transportable radio transmitting set No. 7.
AN/FPS-5-T1	Training set No. 1 for fixed radar search set No. 5.

PURPOSE

A—auxiliary assemblies (not complete operating sets)

C—communications (receiving & transmitting)

D—direction finder

H—recording (includes sound recording and picture taking equipment

G—gun directing

L—searchlight control

M—maintenance and test assemblies (including tools)

N—navigational aids (including altimeters, beacons, compass & instrument landing)

P—reproducing (includes sound reproducing and picture projecting equipment)

Q—special or combination of types

R—receiving

S—search and/or decting

T—transmitting

W—remote control

X—identification and recognition

NUMBER

The number following the set or equipment indicator letters designates a specific complete set.

MODIFICATION LETTER

Modification letters will be assigned for each modification not affecting interchangeability of the sets or equipments as a whole, except in some special cases they will be assigned to indicate functional interchangeability and not necessarily complete electrical and mechanical interchangeability.

The suffix letters X, Y and Z will be used only to designate a set or equipment modified by changing the input voltage, phase or frequency. X will indicate the first change, Y the second, Z the third, XX the fourth, etc., and these letters will be in addition to other modification letters applicable.

ADDITIONAL INDICATORS

Experimental Sets. In order to identify a set or equipment of an experimental nature with the development organization concerned, the following indicators will be used within the parentheses:

XA—Aircraft Radio Laboratory
XC—Camp Coles Signal Laboratory
XE—Camp Evans Signal Laboratory
XM—Fort Monmouth Signal Laboratory
XN—Navy
XO—Eatontown Signal Laboratory
XP—Army Pictorial Service
XR—NDRC — Division 14
XT—Toms River Signal Laboratory
XW—Watson Laboratories

Example: Radio Set AN/ARC-3( ) might be assigned for a new airborne radio communication set under development. The cognizant development organization might then assign AN/ARC-3 (XA-1), AN/ARC-3 (XA-2), etc., type numbers to the various sets developed for test. When the set was considered satisfactory for use, the experimental indicator would be dropped and procurement nomenclature AN/ARC-3 would be assigned thereto.

Training sets. A set or equipment designed for training purposes will be assigned type numbers as follows:

A set to train for a specific basic set will be assigned the basic set type number followed by a dash, the letter T, and a number. Example: Radio Training Set AN/ARC-6A-T1 would be the first training set for Radio Set AN/ARC-6A. A set to train for general types of sets will be assigned the usual set indicator letters followed by a dash, the letter T, and a number. Example: Radio Training Set AN/ARC-T1 would be the first training set for general airborne radio communication sets.

Summary of Joint Army-Navy Nomenclature System ("AN" System) For Communication and Associated Equipment.

EXAMPLE OF COMPONENT TYPE NUMBER: T-2B/ARC-6A

MEANING: T — **RADIO TRANSMITTER**

TABLE OF COMPONENT INDICATORS

Comp. Ind.	Family Name	Definations or Examples — Not to be construed as limiting the application of the component indicator to those items.
AB	Antenna Supports	Antenna mounts, mast bases, mast sections, towers, etc.
AM	Amplifiers	Power, audio, interphone, radio frequency, panoramic, etc.
AS	Antenna Assemblies	Complex: Arrays, parabolic type, masthead, etc.
AT	Antennae	Simple: Whip or telescopic, loop, dipole, reflector, etc.
BA	Battery, primary type	B-batteries, battery packs, etc.
BB	Battery, secondary type	Storage batteries, battery packs, etc.
BZ	Audible Signal Devices	Buzzers, Gongs, horns, etc.
C	Control Articles	Control box, remote tuning control, control unit, etc.
CG	R.F. Cables & Transmisson Line	R.F. cables, wave guides, etc. with terminals.
CK	Crystal Kits	A kit of crystal units.
CM	Compararators	Analyzes or compares two or more input signals.
CN	Compensators	Electrical & or mechanical compensating, regulating or attenuating apparatus.
CP	Computers	A mechanical & or electronic mathematical calculating unit.
CR	Crystal Units	Crystal in crystal holder.
CU	Coupling Units	Impedance coupling devices, directional couplers, etc.
CV	Converters (electronic)	Electronic apparatus for changing the phase, frequency, or from one medium to another.
CW	Covers	Cover, bag, roll, cap, radome, nacelle, etc.
CX	Cords	Cord with terminals, also composite cables of R.F. and non-R.F. conductors.
CY	Cases	Rigid and semi-rigid structure for housing or carrying equipment.
DT	Decting Heads	Magnetic pick-up device, search coil, etc.
DY	Dynamotors	Dynamotor power units.
F	Filters	Band-pass, noise, telephone, wave traps, etc.
FN	Furniture	Chairs, Desks, Tables, etc.
G	Generators (see PU)	Electrical power generators without prime movers.
GO	Goniometers	Gonimeters of all types.
GP	Ground Rods	Ground Rods, stakes, etc.
H	Head, Hand & Chest Sets	Also includes earphone unit.
HC	Crystal Holders (without crystal)	
HD	Air Conditioning Apparatus	Heating, Cooling, dehumidifying, pressure units, vacuum units, etc.
ID	Indicators	Azimuth, plan position, elevation, panoramic, calibrated dials & meters, indicating light, etc.
IL	Insulators	Strain, stand-off, feed-through, etc.
J	Junction Units	Junction, jack & terminal boxes; connector panels, etc.
KY	Keying Devices	Mechanical, electrical and electronic keyers, coders, interrupters, etc.
LC	Line Construction Tools	Includes special apparatus such as cable plows, hoists, etc.
LM	Illuminating Lamps and Bulbs	
LS	Loudspeakers	Separately housed loudspeakers.
M	Microphones	Radio, telephone, throat, hand, etc.
MD	Modulators	Device for varying amplitude, frequency or phase of alternating current.
MK	Maintenance Kits or Equipments	Radio, telephone, general utility, etc.
ML	Meteorological Apparatus	Barometer, hygrometer, thermometer, scales, etc.
MT	Mountings	Mountings, frames, stands, etc.
MX	Miscellaneous	Equipment not otherwise classified.
O	Oscillators	Master frequency, blocking, multivibrators, etc. For test oscillators see TS.
OA	Operating Assemblies	Operating units mounted together not otherwise covered.
PF	Pole Fittings	Cable hangers, clamps, etc.
PG	Pigeon Articles	Container, loft, vest, etc.
PH	Photographic Articles	Camera, projector, sensitometer, etc.
PP	Power Supplies	Non-rotating machine type such as vibrator pack, rectifier, thermo-electric, etc.
PT	Plotting Equipments	Exact meteorological. Boards, maps, plotting table, etc.
PU	Power Equipments	Rotating power equipment except dynamotors. Electric motors, combustion type engines, etc.

2	B	PART OF OR USED WITH	A	R	C	6	A
NO. & MOD. LETTER		SLANT	TABLE OF SET OR EQUIPMENT INDICATOR LETTERS			NO. MOD. LETTER	
Modification letters will be assigned for each modification when parts are no longer interchangeable. Different numbers will be assigned to components not electrically & mechanically interchangeable as a whole. The component will retain its original nomenclature even though later made part of other equipment.		Slant separates component and set designations. Indicates component is part of or used with the set or equipment designated.	Installation See Table I	Type of Equipment See Table I.	Purpose See Table I.	See Table I.	

EXAMPLES OF AN TYPE NUMBERS

Type Number	Indicates
R-10 CRN-8A	Radio receiver No. 10, part of or used with air transportable radio navigation set No. 8A.
C-11 VRC-T1	Control box No. 11, part of or used with training set No. 1 for general vehicular radio communications.
TK-4 GR	Tool kit No. 4 for general ground radio equipment, not part of a specific set.

Table of Component Indicators (Cont'd)

R	Radio & Radar Receivers	Radio or radar receivers, combined unit such as Receiver-Indicator, etc.
RD	Recorders & Reproducers	Tape, facsimile, disc, magnetic, etc.
RE	Relay Assemblies	Electric, Electronic, etc.
RF	Radio Frequency Units	Miscellaneous radio frequency apparatus.
RG	Bulk R.F. Cables & Transmission Line	R.F. cable, wave guides, etc. without terminals.
RL	Reel Assemblies	Antenna, field wire, etc.
RP	Rope & Twine	Non-electrical cord, etc.
RR	Reflectors	Target, confusion, etc. Except antenna reflectors. (see AT)
RT	Receiver and Transmitter	Radio and Radar transceivers, transmitter and receiver in one unit, etc.
S	Shelters	House, tent, protective shelter, etc.
SA	Switching Assemblies	Manual, impact, motor driven, pressure operated, etc.
SB	Switchboards	Telephone, fire control, power, panel, etc.
SM	Simulators	Flight, aircraft, target, signal, etc.
SN	Synchronizers	Equipment to co-ordinate two or more functions.
ST	Straps	Harness, straps, etc.
T	Radio & Radar Transmitters	Communications, range, marker beacon, interrogator, combined Transmitter-Modulator, etc.
TA	Telephone Apparatus	Miscellaneous telephone equipment.
TD	Timing Devices	Mechanical and electronic timing devices, etc.
TF	Transformers	Transformers when used as a separate units.
TH	Telegraph Apparatus	Miscellaneous telegraph apparatus.
TK	Tool Kits or Equipments	Miscellaneous tool assemblies.
TL	Tools	All types except line construction.
TN	Tuning Units	Receiver, transmitter, antenna, etc.
TS	Test Equipments	Test & measuring equipment including dummy antenna, pickup probes, etc.
TT	Teletypewriter & Facsimile Apparatus	Miscellaneous tape, teletype, facimile equipment, etc.
U	Audio & Power Connectors	Unions, plugs, sockets, adapters, etc.
UG	R.F. Connectors	Unions, plugs, sockets, choke couplings, adapters, elbows, flanges, etc.
V	Vehicles	Carts, dollies, trucks, trailers, etc.
VS	Visual Signaling Equipments	Flag sets, aerial panels, signal lamp equipment, etc.
WD	Two Conductor Cables	Includes non-R.F. wire, cable & cordage in bulk.
WF	Four Conductor Cables	Includes non-R.F. wire, cable & cordage in bulk.
WM	Multiple Conductor Cables	Includes non-R.F. wire, cable & cordage in bulk.
WS	Single Conductor Cables	Includes non-R.F. wire, cable & cordage in bulk.
WT	Three Conductor Cables	Includes non-R.F. wire, cable & cordage in bulk.

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TYPE	FREQUENCY RANGE (Mc)	RATED TRANS OUTPUT (Watts)	TYPE EMISSION	TYPE MOD	FREQUENCY CONTROL	PRESET CHANNELS	INSTRUCTION BOOK	REMARKS
AN/CRC-2	100 to 156	8	voice	am	xtal	4	AN 16-30CRC2-2	For communication with aircraft. Provides for simultaneous reception on six frequencies, and at the same time; voice transmission on any one of four frequencies. Eight vertical half-wave antennas mounted in pairs on 50 ft. ply wood masts.
AN/CRN-5	100 to 156	90 105	tone voice	am	xtal	—	AN 16-30MRN2-2	Vertically polarized two course aural radio range equipment with station identification, periodic quadrant identification and simultaneous voice transmission.
AN/CRN-11	0.2 to 0.4	50	tone voice	am	mo or xtal	—	TM 11-1077	Loop type four-course radio range ground station. Transmits tone modulated signal, using A-N keying, to provide courses for aircraft.
AN/MRC-1	trans. (incl. ampl.) 2.0 to 13.0 trans. (less ampl.) 2.0 to 18.0 2 receivers, 1.5 to 18.0	2000 400 300	cw cw voice	am	mo or xtal	—	TM 11-602	Ground, mobile; provides facilities for high power, high-speed automatic c-w transmission and reception employing Boehme equipment in addition to the normal functions of Radio Set SCR-399. The radio transmitter power amplifier and one radio receiver are housed in the transmitting Shelter HO-17, with three radio receivers and the Boehme equipment housed in the operating Shelter HO-17 or HO-27. Requires three 2½-ton, 6 x 6 cargo trucks for transportation. 15-ft. whip or half-wave doublet antenna.

Characteristics of Ground Radio Equipment

TYPE	FREQUENCY RANGE (Mc)	RATED TRANS OUTPUT (Watts)	TYPE EMISSION	TYPE MOD	FREQUENCY CONTROL	PRESET CHANNELS	INSTRUCTION BOOK	REMARKS
AN/MRC-2	trans. 2.0 to 18.0 rec. 1.5 to 18.0	2000 (incl. ampl.) 400 (less ampl.) 300 (less ampl.)	cw & special cw voice	am	mo or xtal	—	TM 11-624	Ground, mobile; provides a single - channel radio - teletype system using carrier-shift keying and dual space-diversity reception in addition to the normal facilities of Radio Set SCR-399. Equipment housed in three shelters HO-17 or HO-27. Frequency range of 2 kw power amplifier is 1.0 to 18.0 Mc. Frequency Conversion Kit MC-509 gives transmitter coverage down to 1.0 Mc. Half-wave doublet antenna.
AN/TRC-1	70 to 100	50 or 10	voice	fm	xtal	—	TM 11-2601	For single channel, or multi-channel operation with spiral-four carrier terminal equipment. High or low power by switch control. Three element directional array on 40 ft. mast.
AN/TRC-3	70 to 100	50 or 10	voice	fm	xtal	—	TM 11-2601	Radio terminal set *similar to AN/TRC-1* except has sufficient equipment to insure continuous service. High or low power by switch control. Three element directional array on 40-ft. mast.
AN/TRC-4	70 to 100	50 or 10	voice	fm	xtal	—	TM 11-2601	Radio relay set *similar to AN/TRC-1* except has sufficient equipment to insure continuous service as a repeater station. High or low power by switch control. Three element directional array on 40-ft. mast.

Characteristics of Ground Radio Equipment

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TYPE	FREQUENCY RANGE (Mc)	RATED TRANS OUTPUT (Watts)	TYPE EMISSION	TYPE MOD	FREQUENCY CONTROL	PRESET CHANNELS	INSTRUCTION BOOK	REMARKS
AN/TRC-2	2.0 to 3.4 and 3.8 to 6.5	20/10* 7/5* 7/5*	cw tone voice	am	mo or xtal	—	TM 11-2603	Two receiver-transmitters for use by isolated units. Quarter-wave inverted L antenna with counterpoise or half-wave antenna without counterpoise. Lower values of power than those indicated may be obtained by switch control.
AN/TRC-5	1350 to 1500	200	voice	pulse	magnetron	—	TM 11-626	Radio terminal or relay set. Provides simultaneous two-way communication on eight voice frequency channels. Parabolic reflector type antennas.
AN/TRC-6	4300 to 4900	2	voice	pulse	klystron	—	TM 11-632	Radio terminal or relay set. Provides simultaneous two-way communication on eight voice frequency channels. Parabolic reflector type antennas.
AN/TRC-7	100 to 156	0.5	voice	am	xtal	2	TM 11-617	Transportable; light weight radio set, transportable by a 4-man team. Quarter-wave whip, or vertical broad-band antenna on 30 ft. mast.

*When two values of power are shown separated by a slant bar (/), the higher value in general applies to ground, transportable, and vehicular operation; the lower value to pack operation.

Characteristics of Ground Radio Equipment

RESTRICTED

TYPE	FREQUENCY RANGE (Mc)	RATED TRANS OUTPUT (Watts)	TYPE EMISSION	TYPE MOD	FREQUENCY CONTROL	PRESET CHANNELS	INSTRUCTION BOOK	REMARKS
AN/TRC-8	230 to 250	12	voice	fm	mo (temp. compensated)	—	TM 11-618	For single channel or multi channel operation with spiral-four carrier terminal equipment. Half-wave dipole and 90 corner reflector on 40 ft. mast.
AN/TRC-11	230 to 250	12	voice	fm	mo (temp. compensated)	—	TM-11-618	Radio terminal set SIMILAR TO AN TRC-8 except has sufficient equipment to insure continuous service. Half-wave dipole and 90 corner reflector on 40 ft. mast. mast.
AN/TRC-12	230 to 250	12	voice	fm	mo (temp. compensated)	—	TM-11-618	Radio relay set SIMILAR TO AN TRC-8 except has sufficient equipment to insure continuous service as a repeater station. Half-wave dipole and 90° corner reflector on 40 ft. mast. on 40 ft. mast.
SCR-188-A	trans, 1.5 to 12.5 rec. 1.5 to 18.0	75	cw tone voice	am	mo	—	TM 11-233	Ground, transportable: for semi-fixed use arranged for remote control; 1/4 or 3/4 wave inverted L antenna with counterpoise. Transported by vehicle or cargo aircraft.
SCR-277	trans. 0.2 to 0.4 rec. 1.5 to 18.0	810	cw tone voice	am	mo	—	AN 16-10-10	Mobile, loop type four-course radio range ground station. Transmits tone modulated signal, using A-N keying, to provide courses for aircraft navigation.

Characteristics of Ground Radio Equipment

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TYPE	FREQUENCY RANGE (Mc)	RATED TRANS OUTPUT (Watts)	TYPE EMISSION	TYPE MOD	FREQUENCY CONTROL	PRESET CHANNELS	INSTRUCTION BOOK	REMARKS
SCR-291-( )	rec. 2 to 10	—	cw tone voice	am	—	—	TM 11-243	Air transportable direction finder. Provides instantaneous visually indicated bearings. Employs a non-rotating type of Adcock antenna, consisting of four spaced monopoles and a sense antenna.
SCR-499 SCR-399	Trans, 2.0 to 18.0 2 rec, 1.5 to 18.0	400 300	cw voice	am	mo or xtal	—	TM 11-281	SCR-399 is mobile. SCR-499 is air transportable; high power radio station similar to SCR-399 except arranged for transportation by air. 15-ft. whip or half-wave doublet antenna.
SCR-509	20.0 to 27.9	1.8	voice	fm	xtal	2	TM 11-605	Pack; operates on dry batteries from stationary position. 8 ft. whip.
SCR-573	2 trans, 100 to 156	50	tone voice	am	xtal	2	AN 16-40SCR573-2	Mobile transmitting station for ground control of fighter operations. Uses half-wave dipolos on 75 ft. plywood mast.
SCR-574	2 receivers, 100 to 156		cw tone voice	am	Manual tuning (xtal cal.)	2	AN 16-40SCR574-2	Mobile receiving station for ground control of fighter operations. Uses half-wave dipoles on 75 ft. plywood mast.

Characteristics of Ground Radio Equipment

RESTRICTED

TYPE	FREQUENCY RANGE (Mc)	RATED TRANS OUTPUT (Watts)	TYPE EMISSION	TYPE MOD	FREQUENCY CONTROL	PRESET CHANNELS	INSTRUCTION BOOK	REMARKS
SCR-575	2 receivers 100 to 156 SCR-522 100 to 156		cw tone voice	am	Manual tuning (xtal cal.)		AN 16-40SCR575-3	Mobile d-f station used either as a fixer or homer station for ground control of fighter operations. For obtaining bearings on aircraft having 100 to 156 Mc radio equipment. Uses Adcock antenna with sensing facilities.
SCR-624	100 to 156	8	voice	am	xtal	4	AN 16-40SCR624-2	Air transportable; similar to SCR-522 and SCR-542 airborne sets except arranged for ground use. Vertical half-wave J antenna on 50 ft. mast.
SCR-634	rec. 100 to 156	—	cw tone voice	am	manual tuning	—	AN 16-40SCR634-2	Air transportable d-f station used primarily with similar units as a fixer d-f station or, with the addition of Radio set SCR-624, as a homer d-f station. Use Adcock antenna with sensing facilities.

Characteristics of Ground Radio Equipment

RESTRICTED

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TYPE	FREQUENCY RANGE (Mc)	RATED TRANS OUTPUT (Watts)	TYPE EMISSION	FREQUENCY CONTROL	PRESET CHANNELS	POWER SOURCE	INSTRUCTION BOOK	REMARKS
AN/ARC-3	100 to 156	8	tone voice	xtal	8	28v, d-c	AN 16-30ARC3-3	For 2-way plane-to-plane and plane-to-ground communication. Automatic tuning of transmitter and receiver upon insertion of crystal.
AN/ARC-8	trans. 0.2 to 1.5 & 2.0 to 18.1 rec. 0.2 to 0.5 & 1.5 to 18.0	100 50	cw tone voice	mo (xtal cal.)	trans 11	28v, d-c	AN 16-30ART13-3 AN 16-40BC224-2	One preset channel is between 0.2 and 1.5 Mc and ten are between 2.0 and 18.1 Mc. Half power is automatically obtained upon reaching an altitude of approximately 25,000 feet.
AN/ARN-5	332.6, 333.8 and 335.0	—	tone	xtal	3	28v, d-c	AN 16-30ARN5-2	Instrument Low Approach glide path receiver. Output of receiver fed into crosspointer meter. Position of horizontal pointer of meter with respect to center of meter face gives pilot indication of whether to fly up or down to remain on a predetermined descent path to ground.
AN/ARN-7	0.1 to 1.75	—	cw tone voice	Manual tuning	—	115v at 400 cycles and 28v, d-c	AN 16-30ARN7-3	Receiving and direction-finding set which may be used as an automatic direction finder, a standard receiver, or a shielded loop receiver.
AN/ARN-11	0.2 to 0.4 0.55 to 1.2 2.9 to 6.0	—	cw tone	Manual tuning	—	28v, d-c	AN 16-30ARN11-3	Receiving and direction-finding set which may be used as a direction-finder, a standard receiver, or a shielded loop receiver.

*All sets are amplitude-modulated.

Characteristics of Airborne Radio Equipment

TYPE	FREQUENCY RANGE (Mc)	RATED TRANS OUTPUT (Watts)	TYPE EMISSION	FREQUENCY CONTROL	PRESET CHANNELS	POWER SOURCE	INSTRUCTION BOOK	REMARKS
RC-103-A & RC-103AZ	108.3 to 110.3	—	tone voice	xtal	6	28v, d-c 14v, d-c	AN 16-40RC103-2	Instrument Low approach localizer receiver. Output of receiver fed into crosspointer meter. Position of vertical pointer of meter with respect to center of meter face gives pilot indication of whether to fly right or left or remain on a course aligned with the runway.
RC-193-A & RC-193-AZ	75	—	tone	—	1	28v, d-c 14v, d-c	AN 16-40RC193-2	Airborne marker beacon receiver designed to furnish visual indications to the pilot of an aircraft upon reception of marker beacon signals associated with the Instrument Low Approach System or radio range fan and "Z" markers.
SCR-269-G	0.2 to 1.75	—	cw tone voice	Manual tuning	— —	115v at 400 cycles and 28v, d-c	AN 16-10-175	Receiving and direction-finding set which may be used as an automatic direction-finder, a standard receiver or a shielded loop receiver.
SCR-274-N	trans. 30.0 to 9.1 rec. 0.19 to 0.55 & 3.0 to 9.1	36 12	cw tone voice	mo (xtal cal.)	1 (per trans.)	28v, d-c	AN 16-10-50	Provides 2-way plane-to-plane and plane-to-ground communication. Frequency range shown is covered by four transmitters and three receivers, not necessarily all used in one installation.
SCR-287	trans. 0.35 to 0.65 & 1.5 to 12.5 rec. 0.2 to 0.5 & 1.5 to 16.0	75	cw tone voice	mo	none	28v, d-c	AN 16-40BC375-2 AN 16-40BC224-2	Provides 2-way plane-to-plane and plane-to-ground communication.
SCR-522	100 to 156	6	voice	xtal	4	28v, d-c	AN 16-40SCR522-3	For 2-way plane-to-plane and plane-to-ground communication.

Characteristics of Airborne Radio Equipment

TYPE	AN/CPS-1 EW, Air-trans	AN/CPS-4 Mobile, air-transportable height finder	AN/CPS-5 Air-Transportable EW, Mobile (when Modified)
WEIGHT (tons)	66	15	19
MAX. RANGE (miles)	210	80	200
FREQUENCY (Mc)	2700-2900	2700-2900	1280-1350
PULSE-LENGTH (MICRO-Sec.)	1	.9	4
PEAK POWER (Kw)	700	750	250-500
ANTENNA TYPE	Parabolic cylinders fed by linear dipole arrays.	Elliptical section of a paraboloid fed by a waveguide horn. (Beavertail)	Parabola mounted on 25' tower
POLARIZATION	Lower beam—Vertically High beam—Horizontally	Horizontal	Horizontal
ANTENNA GAIN		Approx. 3500	1000
BEAM WIDTH Azimuth Elevation	0.8 degree 3.0 degrees	4.8 degrees 1.2 degrees	2 degrees 9 degrees
INDICATORS A PPI B RHI J	Standard No. / Max. No. 1-5" 5-12" / 12-12" 5-7" / 8-7"	2-5" 2-12" 1-12"	1-5" 2-12"
ACCURACY Range Azimuth Elevation	½ mile ½ degree None	1 Mile .24 degrees	1 Mile 1 Degree None
SHELTERS	4 Jamesway	2 Jamesway	4 Jamesway or 2½ ton trucks for mobile operation
ASSEMBLY TIME	3 days, 90 men	24 hours, 30 men	24 hours, 30 men
ADVANTAGES	High traffic handling capacity, good continuity of plotting, good low and high angle coverage, freedom from siting difficulties		Very mobile
LIMITATIONS	Heavy. No height-finding provision		No height-finding provision
REMARKS	Modified it becomes the AN/CPS-5 mounted on 11 vehicles. When used with a height-finder forms a good ground control radar	Adaptable as a height-finder to almost all of the heavy search radars such as the AN/CPS-1	

Characteristics of Ground Radar Equipment

TYPE	AN/CPS-6 Air-trans. - long-range EG GCI and general traffic control	AN/TPS-1 Transportable, LWEW long-range search	AN/TPS-10 Transportable Height-finder
WEIGHT (tons)	145	2½	2½
MAX. RANGE (miles)	210	175	60
FREQUENCY (Mc)	2700-3019	1220-1280	9090 (3Cm)
PULSE-LENGTH (MICRO-Sec.)	1		
PEAK POWER (Kw)	750	600	80
ANTENNA TYPE	2 parabolic set at 45° to each other	Dipole in 4 zone of 15' paraboloid	Cut paraboloid reflector.
POLARIZATION	Horizontal	Horizontal	Vertical
ANTENNA GAIN	10,000, 4800, 2200, 3800 & 2500	560	17,000
BEAM WIDTH Azimuth Elevation	1.0 degree 0.7 degree	3 degrees 11 degrees	2.0 degrees 0.7 degree
INDICATORS A PPI B RHI J	Standard No. / Max. No. 8-12" / 12-12" 5-7" / 10-7" 4-12" / 6-12"	1-5" 1-7"	1-3" 1-7"
ACCURACY Range Azimuth Elevation	½ mile ½ mile 500'	1 mile 3 degrees	1 mile 500' at 50 miles
SHELTERS	5 Jamesway	10 cubical tent	10 cubical tent
ASSEMBLY TIME	1 week—90 men	30 minutes, 6 men	3 hours, 6 men
ADVANTAGES	Furnishes three dimensional data on targets	Portability, can be hand carried	Portability
LIMITATIONS	Heavy	No height-finding provision, not designed for continuous operation.	Limited range
REMARKS	Characterized by high traffic handling capacity, good low angle coverage. High resolution with good accuracy.	Good for presiting heavy- search radar sets.	Finds height by means of a narrow pencil-like Beavertail beam.

Characteristics of Ground Radar Equipment

TYPE	SCR-270 Mobile, EW	SCR-527 Mobile, EW GCI	SCR-584 Gun-laying Mobile, TC
WEIGHT (tons)	41.5	45	10
MAX. RANGE (miles)	150	150	70,000 yards
FREQUENCY (Mc)	106	209	3,000
PULSE-LENGTH (MICRO-Sec.)			
PEAK POWER (Kw)	100	150	300
ANTENNA TYPE	Dipoles & Reflectors	Dipoles and Wire screen reflectors—Separate antennas for receiver and transmitter.	Rotating dipole in 6 Paraboloid Reflector
POLARIZA-TION	Horizontal	Horizontal	Horizontal
ANTENNA GAIN	140	60	1200
BEAM WIDTH Azimuth Elevation	28 degrees 10 degrees	12 degrees 24 degrees	4 degrees 4 degrees
INDICATORS A PPI B RHI J	1-5 1-12	1-12 1-12	1-7 2-3
ACCURACY Range Azimuth Elevation	1 Mile	½ mile 2 degrees 1000	15 yds. .6 mils. .6 mils.
SHELTERS	2 vans, 1 stake body truck, antenna trailer.	2 vans 2 antenna trailers	1 van
ASSEMBLY TIME	3 hours, 15 men	4 hours, 30 men	2 hours, 10 men
ADVANTAGES	Designed for continuous operation	Good medium and high angle coverage	Automatic tracking
LIMITATIONS	Heavy, no height-finding provision, low traffic-handling capacity.	Critical to site, low traffic-handling capacity	Low traffic handling capacity
REMARKS			

Characteristics of Ground Radar Equipment

SET NUMBER	AN/CPN-1	AN/CPN-3	AN/CPN-6	AN/CPN-8	AN/PPN-2	AN/TPN-1
TYPE	Responder Beacon Receiver only	Responder Beacon	Responder Beacon	Land Based Responder Beacon	Responder Beacon	Transportable Responder Beacon
WEIGHT (lbs.)	265	1013	2107	1200	33	167
FREQUENCY	3267-3333	3256	9310	3256	214-234	214-234
RANGE	Line of sight 100	Line of sight	Line of sight	100	28 miles Antenna Height 28'	50 miles
PEAK POWER		10 kw	25 kw	3 kw	8-20 watts	15 watts
ANTENNA TYPE	Linear array of 6 circular dipole units on a common vertical shaft. Omnidirectional.	Linear array of 6 triple-dipoles on 21' 3" mast. Separate Rec. & Transmitter ant.	Linear array of 12 slotted wave-guide elements. Both Rec. and Transmitter ant.	Linear array of 14 triple dipoles. Separate Antennas for Trans. & Rec.	Antenna rod mounted on 9½-foot collapsible mast.	12 inch Quarter-wave antenna fed by coaxial cable.
CODING TYPE	Reply Constant and pulsating.	Reply Range	Reply Range	Reply 6 code pips give range-coded reply.	Reply Pulse Length	Reply Morse code
PULSE LENGTH (micro-seconds)		0.5	0.5	0.5-0.6	6 to 12 narrow 12 to 24 wide	8 to 10 or 15 to 20
REMARKS:	Used to provide Navigational and homing aid for aircraft equipped with S-band radar.	Uses same as AN CPN-1.	Used in conjunction with aircraft equipped with 3-cm radar.	Designed to provide range, direction and identification for guidance of aircraft equipped with 10-cm radars.	Commonly called (EUREKA) used with planes equipped with Rebecca interrogators.	Same as AN PPN-2

Characteristics of Radar Beacons

SET NUMBER	AN/TPN-2	AN/UPN-1	AN/UPN-2	YJ-1 (NAVY)
TYPE	Transportable responder beacon	Ultraportable responder beacon	Ultraportable responder beacon	Ground or ship-based responder beacon
WEIGHT	110 lbs.	87	100	100
FREQUENCY (Mc)	214-234	3256	3256	171-181 510-530
RANGE	Line of sight	Line of sight	Line of sight	100
PEAK POWER	50 to 100 watts	50 watts	50 watts (min.)	15 to 150 watts
ANTENNA TYPE	Quarter wave dipole about 11½" long, mounted above a 4-section counterpoise made of 12" rods.	Duplex linear array of six triple-dipoles for transmitting and six for receiving.	Duplex linear array: Six triple-dipoles for receiving, six for transmitting.	2 vertically stacked folded dipoles on a 21' mast for high frequency, 1 for low frequency.
CODING TYPE	Interrogation and reply - Any combination of 2 Morse-code letters.	Reply Range	Reply Range	Reply Gap, any 1 or 2 letters of Morse code.
PULSE LENGTH	10-20	0-6	0.5	10
REMARKS:	Homing beacon for co-operation with Rebecca installation especially for parachute supply missions.	Installation on ground and on ships for use by paratroops.	Beacon answers interrogation by airborne, ship, or ground S-band radars.	Used as a navigational aid to airplanes equipped with search radars that operate on the frequency bands of 171-181 and 510-130.

Characteristics of Radar Beacons

SET NUMBER	AN/CPX-1 (CPX-2)	RC-150	SCR-695
TYPE	Interrogator responsor	Interrogator responsor	Airborne transponder
WEIGHT	5800 lbs.	755 lbs.	44 lbs.
FREQUENCY	157-187	157-187	157-187
RANGE	200	200	Line of sight
ANTENNA TYPE	Dipoles and screen reflectors	Two dipoles with reflectors	Quarter-wave antenna mounted on underside of fuselage.
REMARKS	This system interrogates transponders installed in aircraft from all of which a coded reply is displayed on control-unit A-scope.	Used to interrogate airborne transponders from all of which coded reply is displayed on associated radar scope.	Receives pulses from the interrogator, is tripped into operation and retransmits coded pulses back to original interrogator in the form of the code of the day.

IFF Equipment

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	AN APG-1	AN APG-13A	AN APG-15B
TYPE	Airborne Interception & Gunlaying	Airborne Range—Only Fire Control Radar Gun-Sight	Airborne Radar Gun-sight for Tail Gunner of Very Heavy Bombers
SWEEP RANGES	0-5000 Ft. 0-20,000 Ft. 0-100 Mi. Typical Ranges: Bombers, 10 Mi. Fighters, 8 Mi. Beacon, 100 Mi. Minimum Range, 125 Yds.	0-6,000, 0-24,000 Yards Minimum Range, 300 Yards	Maximum 1,800 Yds. Minimum 200 Yds.
TRANSMITTING FREQUENCY	3,000 MC	2,500 MC	2,500 MC
RECEIVING FREQUENCY	3,000 MC	2,500 MC	2,500 MC
PULSE LENGTH MICRO-SECONDS	Search & Interception 0.75 MS Beacons 2.25 MS	0.7 MS	0.7 MS
PULSE RECURRENCE FREQUENCY PULSES PER SECOND	Search & Interception 1600 PPS Beacons 400 PPS	1,000 PPS	1,200 PPS
ANTENNA TYPE	Rotating Dipole (66 RPS) with 27½ in. Paraboloid Reflector Conical Scan Superimposed on Rectangular Scan Covering 165 in Azimuth and 30 in Elevation	18 Element End-Fire Array in Fixed Cylindrical Housing, Mounted on Top of Fuselage	Fixed Dipole in 12 in. Paraboloid Reflector which is Offset 45° and Rotates 2,400 RPM
HORIZONTAL BEAM WIDTH	9 Degrees	28 Degrees	25 Degrees
VERTICAL BEAM PATTERN	9 Degrees	28 Degrees	25 Degrees
TYPE INDICATORS	One 5-in. B-Scope for Search. One 5 in. B-Scope or Modified C-Scope For Track. Pilot Indicator 3 in. G-Scope for Tracking Only	One 3 in. Cathode Ray Tube using "M" Type Display (A-Scope with Step Marker)	One 2 in. Cathode Ray Tube with G-Type Presentation. Azimuth Read Horizontally. Elevation Read Vertically, Range Indicated by "Wings"
INSTALLED WEIGHT	695 Lbs.	115 Lbs.	125 lbs.
ANTENNA GAIN	310	35 to 40	(Ant. Gain) 45
PEAK POWER	125 KW	0.75 KW	0.75 KW
REMARKS	Blind Interception and Blind Firing of Guns P-61, A-26	Pilot Must Control Aiming in Azimuth Visually Tracking	Directional Search Obtained by Manual Pointing

Characteristics of Airborne Radar Equipment

	AN/APN-3	AN APQ-5B	AN APQ-7 (EAGLE)	AN APQ-13
	Airborne Interrogation Equipment for the Shoran System	Low-Altitude Bombing Attachment to AN/APS-15	Airborne Bombing	Airborne Search and Bombing
	0-1, 0-10, 0-100 Mi. Range is Limited by Line-of-Sight	0-18 N. Mi.	0-30 Fixed 0-160 Fixed 0-10 Expansible to 0-30 Mi.	0-4 N. Mi. 0-10 N. Mi. 0-20 N. Mi. (Expansible 0-4 to 0-31 Mi.) 0-50 N. Mi. Up to 200 Mi. Sweep Delay
	220-270 MC	None (Function of Basic Radar Set)	10,000 MC	10,000 MC
	220-330 MC	None (Function of Basic Radar Set)	Search and Bombing 10,000 MC Beacons 9,300 MC	Search and Bombing 10,000 MC Beacons 9,310 MC
	0.5 MS	None (Function of Basic Radar Set)	0-160 Mi. Range 0.75 MS 0-30 & 0-10 Mi. Range 0.375 MS Beacons 2.0 MS	50 & 100 Mi. Range 1.125 MS 4, 10 & 20 Mi. Range 0.5 MS Beacons 2.25 MS
	930 PPS	None (Function of Basic Radar Set)	0-160 Mi. Range 775 PPS 0-30 & 0-10 Mi. Range 1550 PPS Beacons 388 PPS	50 & 100 Mi. Range 629 PPS 4, 10 & 20 Mi. Range 1348 PPS Beacons 275 PPS
	3 Mast Antennas 3" x 3" x 12" 2 for Transmitting 1 for Receiving	None	Fixed Antenna, End-fed, Colinear Dipole Array Consisting of 150 Dipoles Equipped with Reflectors and Fed by Wave Guide Antenna Enclosed in Air Foil Leading Edge Heated	Same as AN/APS-15 with 30 in. Reflector
	Non-Directional	None (Function of Basic Radar Set)	0.4 Degrees	3 Degrees
	Non-Directional	None (Function of Basic Radar Set)	Cosecant Exponent 2.75 Pattern 90° Below Horizontal No Tilt	Cosecant Squared Pattern 50° Below Horizontal Tilt Limits 12° to 15°
	J-Scope	Modified 5 in. PPI Scope 120° Sector centered at Heading of Aircraft. Plane Oriented at Bottom of Scope	3 in. A-Scope for Tuning Modified 5 in. PPI Showing only 30° to Each Side of Heading. Aircraft Oriented at Bottom of Scope	Same as AN/APS-15
	335 Lbs.	92 Lbs.	1150 Lbs.	343 Lbs.
		(Ant. Gain) None (Function of Basic Radar Set)	1500	800
	12 KW	(Peak Power) None (Function of Basic Radar Set)	50 KW	35 KW
	Operator-Bombardier Equipment Replaces Bomb Sight for Bombing Purposes	Permits Blind Bombing of Ships & Isolated Land Target	Designed for precision Bombing. Limited Navigational Factor not Considered	Same as AN/APS-15 with Computer CP. This set becomes AN/APQ-23

Characteristics of Airborne Radar Equipment

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	AN APS-4	AN APS-13	AN/APS-15 AN APS-15A	SCR-720
TYPE	Airborne Interception	Airborne Tail-Warning Radar	Airborne Search and Bombing	Night Fighter, Airborne Interception Equipment
SWEEP RANGES	0-4, 0-20, 0-50, 0-100 Mi. Typical Ranges Bomber, 5 Mi. Fighters, 3 Mi. Large Ships, 50 Mi. Land, 90 Mi. Beacons, 100 Mi.	Maximum 800 Yds. Minimum 200 Yds.	0-5 N. Mi. 0-20 N. Mi. (Expansible 0-4 to 0-31 Mi.) 0-50 N. Mi. 0-100 N. Mi. Up to 200 Mi. Sweep Delay	0-2, 0-10, 0-20, 0-100 Mi. Typical Ranges Bombers, 8-10 Mi. Fighters, 6-8 Mi. Beacons, 100 Mi. Minimum Range, 100 Yds.
TRANSMITTING FREQUENCY	9,375 MC	410-420 MC	9,375 MC	3,000 MC
RECEIVING FREQUENCY	9,375 MC	410-420 MC	Search and Bombing 9,375 MC Beacons 9,310 MC	3,000 MC
PULSE LENGTH MICRO-SECONDS	Search & Interception 0.6 MS Beacons 2.1 MS	0.4 to 0.5 MS	50 & 100 Mi. Range 0.95 MS 5 & 20 Mi. Range 0.5 MS Beacons 2.1 MS	Search & nterception 0.75 MS Beacons 2.25 MS
PULSE RECURRENCE FREQUENCY PULSES PER SECOND	0-4, 0-20, 0-50 Mi Ranges 1,000 PPS 0-100 Mi. Range 600 PPS Beacons 350 PPS	300 to 450 PPS	50 & 100 Mi. Range 650 PPS 4 & 20 Mi. Range 1010 PPS Beacons 300 PPS	0-2, 0-10, 0-20 Mi. Range 1500 PPS 0-100 Mi. Range & Beacons 375 PPS
ANTENNA TYPE	Feed Horn Mounted on Wave Guide with 14 in. Parabolic Reflector. Antenna Scans 150° Centered at Aircraft Heading	2 Sets of Folded Dipoles Each with Director and Reflector. Mounted on Vertical or Horizontal Stabilizer	Pressurized Cutler Feet to 29 in. Parabolid Reflector. Antenna & Reflector Rotate Through 360 Degrees	Dipole Antenna with 29 in. Parabolic Reflector Rotates through 360° at 360 RPM on Search, 100 RPM on Beacon. Rear 180° Blacked Out
HORIZONTAL BEAM WIDTH	5.8 Degrees	60°, 30° to Each Side	3 Degrees	10 Degrees
VERTICAL BEAM PATTERN	7.2 Degrees Air Search, Alt. Sweeps 6° Apart. Ground Search, Alt. Sweeps 4° Apart. Antenna Scans a 24° Vertical Sector, Selected by Operator Between Limits of —34° and +28°	90°, 45° Above and Below	Cosecant Squared Pattern 70° Below Horizontal Tilt Limits —20° to +20°	10 Degrees Tilt Limits —10° to +60°
TYPE INDICATORS	One 3 in. Cathode Ray Tube B-Scan for Search and Modified H-Scan (Double Dot) for Intercept	Blinking Redlight and Warning Bell	3 In. A-Scope for Tuning 5 in. PPI Display 360° Scan with Aircraft Oriented with Center of Scope	One 5-in. B-Scope for Range & Azimuth. One 5 in. C-Scope for Altitude & Azimuth Pilot Indicator one 3 in. B-Scope (Optional)
INSTALLED WEIGHT	193 lbs.	21 Lbs.	343 Lbs.	490 Lbs.
ANTENNA GAIN	900 (Ant. Gain)	(Ant. Gain)	200 (Approx.)	340
PEAK POWER	35 KW	450 Watts	40 KW (Approx.)	100 to 150 KW
REMARKS	Usually Employed with Ground or Shipboard Radar	On Fighter Aircraft to Warn Pilot of Aircraft Approaching from Rear	Permits Area Bombing	Usually Employed with Long Range Ground Radar

Characteristics of Airborne Radar Equipment

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ConAC Manual 52-1

RADIOLOGICAL DEFENSE COURSE

- for -

SURVEY AND MONITOR PERSONNEL

MITCHEL AIR FORCE BASE, N.Y.

PREPARED BY
ARMAMENT DIVISION
DIRECTORATE OF OPERATIONS & TRAINING
ConAC

1 SEPTEMBER 1949

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WARNING — THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18 U.S.C., SECTIONS 793 AND 794. ITS TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW. REPRODUCTION OF CONTENTS IS AUTHORIZED PROVIDED SECURITY REQUIRED BY AF REGULATION 205-1 IS MAINTAINED.

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RADIOLOGICAL DEFENSE COURSE FOR SURVEY AND MONITOR PERSONNEL

HEADQUARTERS, CONTINENTAL AIR COMMAND
MITCHEL AIR FORCE BASE, NEW YORK

Subject course is published for the information and guidance of all concerned.

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NOTES TO INSTRUCTORS

1. The attached course has been prepared for the purpose of training Officers and Noncommissioned Officers to function as unit radiological defense personnel capable of performing survey officer and monitoring duties.

2. Airmen should possess a high school education and have a minimum AGCT level of 90 as prerequisites to attendance. An individual obviously unfitted for the course should be dropped, as he will impede instruction.

3. Graduates of one of the Armed Services Radiological Defense Schools are the only individuals qualified to present the bulk of this instruction. Certain individuals, without such training, but with specialized training in a particular field may present the portions dealing with medical aspects, classical physics and nuclear physics.

4. Course material has been developed to present the maximum amount of material possible in a short time. It is recommended, therefore, that the course outline and subject material be presented, essentially, verbatim. A lesser amount of instruction is not deemed adequate to train individuals effectively in radiological defense duties.

5. Lecture outlines are complete with the exception of those periods devoted to monitoring field problems. Local variations in availability of instruments, radium sources and training facilities make it desirable that these periods be left to local instructors for detailed preparation. The instructor should spend at least two hours in preparation for each hour of instruction in order that students' questions may be answered promptly, accurately and simply. The charts which are included with each subject outline are considered an integral part thereof. Local reproduction of these charts is desirable but, if impractical, they can be reproduced on a blackboard with a minimum of effort.

6. Considerable simplification of highly involved phenomena has been employed in the interests of easier teaching. This simplification has impaired strict scientific accuracy, in a few instances, but this is felt permissible for the scope of training envisioned.

7. Adequate facilities are essential for the conduct of this course. These include a classroom with student tables, facilities for evening study by students, a level, secluded area or well-lighted building for calibration work and a restricted area for survey exercises.

8. It is recommended that the theory of calibration and instrument operation be taught during the interim period pending the procurement and distribution of radiation sources and detection instru-

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ments. The practical application and field problems for this training will of necessity have to be postponed until such time as the required materiel is available.

9. It is recommended that each student's final grade be based on a composite score tabulated as follows:

Item	Maximum Number of Points
General Attitude	10
Exam I	45
Preparation of Calibration Curve (Tng Outline 12)	5
Calibration of 263A Survey Meter (Tng Outline 16)	5
Calibration of 247A Survey Meter (Tng Outline 18)	5
Survey Exercise w/263A (Tng Outline 23)	5
Survey Exercise w/247A (Tng Outline 24)	5
Exam II	20
TOTAL	100

An individual scoring less than 70 should not be considered as successfully completing the course. Successful students should be awarded a suitable certificate.

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SCHEDULE

FIRST DAY

0800-0850	Tng Outline 1	Class Organization (Administrative Time)
0900-0950	Tng Outline 2	Introduction and History
1000-1050	Tng Outline 3	Atomic Particles. Structure of Matter
1100-1150	Tng Outline 4	Electro-magnetic Radiation & Radioactivity
1300-1350	Tng Outline 5	Nuclear Reactions, Atomic Fission and Chain Reactions
1400-1450	Tng Outline 6	Explosion Phenomena
1500-1550	Tng Outline 7	Effects of the Atom Bomb on the Human Body
1600-1650	Tng Outline 7	" " " " " " " " "

SECOND DAY

0800-0850	Tng Outline 8	Review of Basic Arithmetic
0900-0950	Tng Outline 9	Practice on Assigned Mathematical Problems
1000-1050	Tng Outline 10	Logarithms & Calculation of Multiple Half-Life Decay
1100-1150	Tng Outline 11	Preparation of Instrument Calibration Curves
1300-1350	Tng Outline 12	Student Preparation of Instrument Calibration Curves
1400-1450	Tng Outline 13	Principles of Radiation Detection Instruments
1500-1550	Tng Outline 14	Operation of 263A G-M Survey Meter
1600-1650	Tng Outline 14	" " " " " "

THIRD DAY

0800-0850	Tng Outline 15	Examination I
0900-0950	Tng Outline 15	" "
1000-1050	Tng Outline 17	Operation of 247A Ion Chamber Survey Meter
1100-1150	Tng Outline 19	Radiation Dosimetry
1300-1350	Tng Outline 16	Student Calibration of 263A Survey Meters
1400-1450	Tng Outline 16	" " " " " "
1500-1550	Tng Outline 16	" " " " " "
1600-1650	Tng Outline 20	Monitoring Techniques

FOURTH DAY

0800-0850	Tng Outline 18	Student Calibration of 247A Survey Meters
0900-0950	Tng Outline 18	" " " " " "
1000-1050	Tng Outline 18	" " " " " "
1100-1150	Tng Outline 21	Individual and Collective Protection
1300-1350	Tng Outline 23	Monitoring Field Problem - 263A Survey Meter
1400-1450	Tng Outline 23	" " " " " "
1500-1550	Tng Outline 23	" " " " " "
1600-1650	Tng Outline 23	" " " " " "

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FIFTH DAY

0800-0850	Tng Outline 24	Monitoring Field Problem - 247A Survey Meter
0900-0950	Tng Outline 24	" " " " " "
1000-1050	Tng Outline 24	" " " " " "
1100-1150	Tng Outline 24	" " " " " "
1300-1350	Tng Outline 22	Decontamination Procedures
1400-1450	Tng Outline 25	Radiological Defense Organization
1500-1550	Tng Outline 25	" " "
1600-1650	Tng Outline 27	Training Programs

SIXTH DAY

0800-0850	Tng Outline 26	Tactical and Strategic Use of Atomic Weapons
0900-0950	Tng Outline 26	" " " " " " "
1000-1050	Tng Outline 28	Effect of the Atomic Bomb on Hiroshina & Nagasaki
1100-1150	Tng Outline 29	Atomic Bomb Explosion - Effects on an American City
1300-1350	Tng Outline 30	Seminar. General Review
1400-1450	Tng Outline 31	Examination II
1500-1550	Tng Outline 31	" "
1600-1650	Tng Outline 32	Administrative Time

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TRAINING OUTLINE NO:	1
LECTURE:	Class Organization (Administrative Time).
TIME:	One (1) hour.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	None.
STUDENTS' REFERENCES:	None.
TRAINING AIDS REQUIRED:	None.

Note to Instructor.

This hour is to be utilized in registering students, distributing training material, assigning seats, and organizing the class in order that instruction may begin with a minimum of disorder.

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TRAINING OUTLINE NO: 2

LECTURE: Introduction and History.

TIME: One (1) hour.

PLACE: Classroom.

INSTRUCTORS' REFERENCES: None.

STUDENTS' REFERENCES: None.

TRAINING AIDS REQUIRED: Projector, Screen, Film "Operations Crossroads" (Misc No. 1323, running time 31 minutes).

1. When the numbered air forces, presently assigned to the Continental Air Command, instituted their post-war chemical training programs, it was generally recommended that only the best qualified commissioned officers and airmen be detailed as unit gas officers and noncommissioned officers. Security considerations at that time precluded giving full reasons for that recommendation, but plans had been drawn for the training of unit gas personnel in radiological defense and biological warfare defense. It was and is considered imperative that personnel of the highest calibre be selected for training in defense against these new modes of warfare. The fact that you are here has placed a grave responsibility on you with respect to your commanding officer and the Continental Air Command as a whole.

2. This course is the "Radiological Defense Course for Survey and Monitor Personnel". Its object is to train radiological survey officers and monitors to be capable of using instruments to detect dangerous radioactivity and qualify these personnel to advise and assist the unit commander in defense against atomic attack. This will be in addition to present gas defense duties. In a tactical situation, effective defense will depend to a great degree upon the recommendation for action given to the unit commander.

3. This course will explore the atom and what goes on inside the atom. It will describe how the atom bomb works, what occurs during atomic fission and what the A-bomb can do to the human body and to buildings. Intensive training will be given in the use of instruments to detect dangerous radioactivity resulting from atomic explosions. And finally there will be instruction in the defensive measures to be taken to minimize casualties in an atomic attack.

4. The work with radiation detection instruments is the essence of the course. Thorough training in the use of these instruments is imperative for an area heavily contaminated with radioactive products looks just like any other terrain. The danger cannot be seen, heard,

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felt, tasted or smelled; it is only by the use of instruments that it can be detected and the necessary measures taken to prevent casualties.

5. This course requires certain simple calculations. This is not a course in mathematics but approximately five hours will be spent in the basic problems of calculation.

6. The need for trained men in this field is urgent; it is no secret that the United States will not always hold its present monopoly on the atomic bomb. Unofficial guesses on the time we have before another major power develops the bomb, range from one to ten years.

7. With reference to security, no "TOP SECRET" material will be presented in this course. Portions of the material are classified as restricted and other sections are not classified at all.

8. A security classification used by the Atomic Energy Commission is that of "RESTRICTED DATA". It is applied to highly classified information about the atomic bomb and atomic energy; it is an Atomic Energy Commission classification, not military, although it may be found in military correspondence. The point to remember is that "RESTRICTED DATA" applies to information of the highest classification, and and must never be confused with the military classification of "RESTRICTED". "RESTRICTED DATA" is to be safeguarded as "TOP SECRET" matter.

9. As an introduction to Radiological Defense, the film, "Operation Crossroads", taken at the Bikini tests in 1946, will be shown. The film gives some idea of the forces against which we must defend ourselves. Besides the blast and the flame, close inspection will show a battleship standing right up on its stern. What is not visible is the flash of deadly radiation - it can kill at a mile at the moment of the burst, or be poisonously radioactive material that is thrown up in the mushroom-shaped atomic cloud, and which is carried downwind to fall invisibly on land and sea, creating a danger for miles. At times in this course the material presented may be slightly at variance with some of the techniques shown in this film. This is due to the fact that Operation Crossroads was a scientific test conducted under conditions differing from combat. In addition, many new developments have occurred since this film was made.

10. There are many precautions to be taken to protect a military unit against the blast of an atomic bomb, but a very important part of the work will consist of being able to detect the "fall out" of radioactive material from the atomic cloud and to take proper action when such contamination is detected.

(FILM, "OPERATION CROSSROADS" WILL BE SHOWN)

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TRAINING OUTLINE NO:	3
LECTURE:	Atomic Particles. Structure of Matter.
TIME:	Fifty (50) minutes.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	Paragraph 2.01, 2.05, 2.07, 5.01-6.01, 6.09, Radiological Defense Manual, Vol 1; Page 12-18, "All Hands", 1 July 1946, Navy Department; Chapter 1, "Atomic Energy for Military Purposes", Smyth; Chapters 1, 2, 3, 4, 11, 12, 13, "General Chemistry" Deming; Chapters I, XXI, XXII, "Outline of Physical Chemistry", Getman and Daniels; Paragraphs 14, 15, 16, 19, 22, 27, 28, 35, 39, 117, 91, 61, "Introduction to Atomic Physics", Semat. (See Footnote*)
STUDENTS' REFERENCES:	Page 12-18, "All Hands", 1 July 1946, Navy Department.
TRAINING AIDS REQUIRED:	Charts appended hereto.

1. Development of the atomic bomb was made possible by an understanding of the minute particles which are the building blocks of all matter. To understand the reason why an atomic bomb works and what results from its detonation requires some knowledge of these particles. It is necessary to know what an atom is, how it is constructed, how it is fissioned (or split), and the results of such a step. While somewhat complicated at first sight, the answers are neither impossible to understand nor difficult to comprehend.

2. The many different kinds of matter which compose the universe are called compounds. Each compound is identified as such by its own characteristic molecule. In other words a molecule is the smallest portion of a compound which can exist and still be that compound. Table salt, a compound called sodium chloride, might be used as an example.

*Chart 3-7 is included for possible use by the instructor. Its purpose is to illustrate the manner in which all matter is built up.

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Suppose we take some table salt and divide it into successively smaller portions. This process could not go on indefinitely, even if we had the proper tools to work with smaller and smaller quantities, since we would reach a point finally where we would have only one molecule of sodium chloride left. This particle would be very small indeed since about one billion of them, laid side by side in a straight line, would only cover one inch. It would still be sodium chloride however and identifiable by chemical analysis, as such.

3. There are about 200,000 different kinds of molecules found in nature and over 500,000 additional kinds have been prepared in the laboratory; making a total of approximately 700,000 compounds known to science today. This figure is very large and if a chemist had to study each separately, his science would be very complicated. This is not necessary, however, because all 700,000 different molecules are combinations of less than one hundred elements. These elements will be considered next.

4. In the example cited above, sodium chloride was broken down to a point where only one molecule was left. Going a step farther and making one more subdivision produces a totally different result. Now the two parts are no longer sodium chloride but one is a substance called sodium, while the second is called chlorine; the table salt exists no longer. These substances, sodium and chlorine, are two elements. There are only 92 elements occurring in nature and these elements are substances which ordinarily cannot be broken down in the chemical laboratory. Some of the more common elements which are found free (i.e., not combined chemically with other elements) in nature are carbon, nitrogen, oxygen, iron, gold, sulfur and silver. If we take a lump of pure silver and carry out the subdivision process that was applied to the molecules of sodium chloride, a point is reached where only one atom of silver is left. This atom of silver is the smallest particle of silver which can exist and still be silver. What happens when this atom of silver is divided will be discussed later.

5. Atoms are the building blocks of chemistry and are the "particles" from which molecules are built. Thus, one atom of sodium combines with one atom of chlorine to form one molecule of sodium chloride which we know as table salt. This may be shown as:

> 1 atom of sodium plus 1 atom of chlorine yields 1 molecule of sodium chloride (table salt)

or as it is written:

$$Na \quad Cl = NaCl$$

Likewise, two atoms of hydrogen combine with one atom of oxygen to form one molecule of water. This is shown as:

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2 atoms of hydrogen plus 1 atom of oxygen yields 1 molecule of water

or

$2 H_2 \; O_2 = 2H_2O$

6. By the year 1919, the existence of 92 elements was known to scientists. The atoms of these 92 elements were thought to be the basic indivisible particles of matter at that time, and the method whereby atoms of these elements combined to form molecules was well understood. It was somewhat of a shock to scientists at large, therefore, when Rutherford found that atoms were divisible and constructed from smaller and still more fundamental particles. With the discovery of fission, four (4) new elements have been added and now there are a total of 96.

7. Before we study these new particles it might be well to point out that the 92 elements which are listed on the sheets distributed,

(INSTRUCTOR - PASS OUT COPIES OF CHART 3-1)

are still the building blocks of modern chemistry and engineering. To break down the atoms of these elements into the really "basic" particles of matter lies outside the field of the modern chemical laboratory and is possible only through use of the giant cyclotrons and other machines of the nuclear physics laboratory. With that point in mind it is now time to investigate the structure of the atoms.

8. Atoms can be compared to miniature solar systems with a heavy central sun which is called the nucleus. This central nucleus if made up of one or more particles which we call protons and, with the single exception of the common hydrogen atom, one or more particles which we can call neutrons. Around the nucleus revolve very much smaller particles called electrons. These three particles; the electron, the proton and the neutron, are the basic particles of matter from which all atoms are constructed.

9. Each of the 92 different atoms is made up of a combination of electrons, protons, and with one exception, neutrons. Thus a generalized picture of the atom may be illustrated by the following diagram:

(INSTRUCTOR - REPRODUCE CHART 3-2)

10. The general properties of these particles may be summed up as follows:

a. The proton is a particle of matter which has a unit

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positive electrical charge and is so small that 20,000,000,000.000,000,000,000 of them would weigh only one ounce.

b. The neutron is a particle of matter which is electrically neutral and very slightly heavier than the proton.

c. The electron is a particle of matter which has a unit negative electrical charge equal in magnitude to the unit positive electrical charge of the proton but is only $\frac{1}{1840}$ as heavy.

(INSTRUCTOR - REPRODUCE THE FOLLOWING TABLE AS THE ABOVE INFORMATION IS PRESENTED)

Particle	Relative Weight	Electrical Charge
Proton	1	Plus 1
Neutron	1	Zero
Electron	1/1840 (Practically zero)	Minus 1

11. The chemical nature of each of the 92 elements is determined by the number of protons in the nucleus of its atom. Thus the Hydrogen atom contains one proton in its nucleus, the Helium atom two protons, the Lithium atom three and so on up to the 92nd element, Uranium, which has 92 protons in its nucleus. Since each atom as a whole is electrically neutral, the plus one charge of each proton must be balanced by an electron containing a minus one charge, and there is one orbital electron present for each proton in the nucleus. Thus the Hydrogen atom has one orbital electron the Helium atom has two orbital electrons, the Lithium atom has three orbital electrons and the Uranium atom 92 orbital electrons. Neutrons are present in the nucleus to the extent of slightly more than a 1 to 1 ratio with protons. By this, we mean that while a Helium atom has two protons and two neutrons in its nucleus, the number of neutrons per proton increases in the larger nuclei so that a Uranium atom is found to have 92 protons and 143 neutrons in its nucleus. Over the entire range the ratio is slightly more than 1 to 1.

12. Elements are assigned atomic numbers in accordance with the number of protons in their respective nuclei. Thus Hydrogen has an atomic number of one, Helium of two and so on. In addition, each element has an assigned mass number. How these mass numbers are arrived at will be taken up later. The difference between this mass number and the atomic number of an element gives the number of neutrons present in the nucleus. An example is Oxygen which has a mass number of 16 and an atomic number of 8. The atomic number of 8 tells us that there are 8 protons in the nucleus. It tells us also that there are 8 orbital electrons. By subtracting the atomic number of 8 from the mass number of 16 we obtain the difference.

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8, and this tells us that there are 8 neutrons in the nucleus.

13. Isotope is a word much used today. To explain its meaning we must dig deeper into the details of atomic structure. In the example quoted above, the element Oxygen was used. We might represent it as follows:

(INSTRUCTOR - REPRODUCE CHART 3-3)

14. There are atoms of oxygen, however, which are represented by the following diagrams:

(INSTRUCTOR - REPRODUCE CHART 3-4)

15. Now each of these three types of the oxygen atom are definitely oxygen atoms because each has 8 protons in its nucleus, however, each has a slightly different weight due to the different number of neutrons present. These different types of oxygen atom are known as isotopes of oxygen. The oxygen present in the atmosphere is a mixture of these isotopes; consisting of 99.76% Oxygen 16, 0.04% Oxygen 17 and 0.20% Oxygen 18. Therefore, in the field of atomic physics we deal not only with elements but with the different isotopes of one element. Some elements have only one isotope while one (tin) has ten isotopes. Each isotope has a definite assigned mass number which is the sum of the total number of particles in its nucleus. It should be emphasized that chemically all the isotopes of one element are identical - the difference is in their weight and therefore their reactions to physical forces.

16. One of the most important tools of the atomic physicist is the cyclotron. This instrument is capable of taking basic particles, such as protons, electrons or neutrons, accelerating these particles to tremendous speeds and then firing them into a target consisting of any one of the 92 elements. There is nothing mysterious about this procedure or its results. A baseball thrown through a glass window produces broken glass. An atomic bullet produces the same result when fired into an atom, although not with the same degree of breakage in most cases. Generally only one proton, one beta particle or one neutron is knocked loose from the nucleus. If a proton is knocked loose from the target atom the atom becomes an atom of a different element, whereas if a neutron is knocked loose the target atom changes to a different isotope of the same element. Two examples will illustrate this:

(INSTRUCTOR - REPRODUCE CHART 3-5 and 3-6)

17. Thus we see that it is possible to smash or fission atoms. These changes are called nuclear reactions and, by proper choice of bullets and target atoms, is the method by which elements are changed into other elements or the isotope of an element is changed into

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other elements or the isotope of an element is changed into another isotope of the same element.

18. Examining the properties of a nucleus more closely, a very curious fact is noted. The nucleus does not weigh as much as it should. A nucleus consisting of six neutrons and six protons should weigh the same as the sum of the weights of six protons plus the weights of six neutrons, thus:

Weight of protons + weight of neutrons = weight of neucleus (REPRODUCE) but, instead, it weighs about 1% less. To explain this unusual situation we must look to Dr. Einstein for assistance. Among the many interesting facts shown by his theory of relativity is the proof that matter may be converted into energy. This relationship is expressed by the simple formula

$$E = mc^2$$

which may be stated in words as, "Energy equals mass times the square of the speed of light." The speed of light is a very large number, 186,272 miles per second, and this means that very small amounts of matter are equivalent to very large amounts of energy. Two examples of the enormous energy involved in infinitesimal amounts of matter are:

a. One pound of matter, of any kind, equals 11.4 billion Kilowatt hours of energy.

b. The total energy equivalent of some 25 pounds of matter is equal to all the power produced in the United States in a year's time.

19. These facts provide a clue as to why the nucleus weighs 1% less than it should. The loss in weight is due to the fact that about 1% of the mass of the components has been transformed into energy. This energy, called the binding energy, is stored in the nucleus where it binds the particles together. Whenever a particle is "smashed" loose from the nucleus, some of this binding energy is no longer required and is released. The energy which is released is what we call atomic energy.

Are there any questions?

<u>INSTRUCTOR'S QUESTIONS:</u>

1. What is the difference between an atom and a molecule?

2. What are the basic particles that are found in an atom?

3. What are isotopes?

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4. What is the significance of $E = mc^2$?

5. Why does a nucleus weigh 1% less than it should?

6. What is atomic energy?

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CHART 3-1

TABLE OF ELEMENTS

	Symbol	Atomic Number	No. of Stable Isotopes		Symbol	Atomic Number	No. of Stable Isotopes
Actinium	Ac	89	0 (A)	Molybdenum	Mo	42	7
Aluminum	Al	13	1	Neodymium	Nd	60	7
Americaium	Am	95	1	Neon	Ne	10	3
Antimony	Sb	51	2	Neptunium	Np	93	6
Argon	A	18	3	Nickel	Ni	28	5
Arsenic	As	33	1	Nitrogen	N	7	2
Astatine	AT	87	0	Osmium	Os	76	7
Barium	Ba	56	7	Oxygen	O	8	3
Beryllium	Be	4	1	Palladium	Pd	46	6
Bismuth	Bi	83	1	Phosphorus	P	15	1
Boron	B	5	2	Platinum	Pt	78	5
Bromine	Br	35	2	Plutonium	Pu	94	2
Cadmium	Cd	48	8	Polonium	Po	84	0
Calcium	Ca	20	6	Potassium	K	19	3
Carbon	C	6	2	Praseodymium	Pr	59	1
Cerium	Ce	58	4	Promethium	Pm	61	0
Cesium	Cs	55	1	Protactinium	Pa	91	0 (B)
Chlorine	Cl	17	2	Radium	Ra	88	0 (C)
Chromium	Cr	24	4	Radon	Rn	86	0
Cobalt	Co	27	1	Rhenium	Re	75	2
Columbium	Cb	41	1	Rhodium	Rh	45	1
Copper	Cu	29	2	Rubidium	Rb	37	2
Curium	Cm	96	2	Ruthenium	Ru	44	7
Dysprosium	Dy	66	6	Samarium	Sm	62	7
Erbium	Er	68	6	Scandium	Sc	21	1
Europium	Eu	63	2	Selenium	Se	34	6
Fluorine	F	9	1	Silicon	Si	14	3
Francium	Fr	85	0	Silver	Ag	47	2
Gadolinium	Gd	64	7	Sodium	Na	11	1
Gallium	Ga	31	2	Strontium	Sr	38	4
Germanium	Ge	32	5	Sulfur	S	16	4
Gold	Au	79	1	Tantalum	Ta	73	1
Hafnium	Hf	72	6	Technitium	Tc	43	0
Helium	He	2	1	Tellurium	Te	52	7
Holmium	Ho	67	1	Terbium	Tb	65	1
Hydrogen	H	1	2	Thallium	Tl	81	2
Indium	In	49	2	Thorium	Th	90	1
Iodine	I	53	1	Thulium	Tm	69	1
Iridium	Ir	77	2	Tin	Sn	50	10
Iron	Fe	26	4	Titanium	Ti	22	5
Krypton	Kr	36	6	Tungsten	W	74	5
Lanthanum	La	57	1	Uranium	U	92	3
Lead	Pd	82	4	Vanadium	V	23	1
Lithium	Li	3	2	Xenon	Xe	54	9
Lutecium	Lu	71	2	Ytterbium	Yb	70	7
Magnesium	Mg	12	3	Yttrium	Y	39	1
Manganese	Mn	25	1	Zinc	Zn	30	5
Mercury	Hg	80	7	Ziroconium	Zr	40	5

(A) Most stable isotope - H.L. of 135 years, (B) Most stable isotope - H.L. of 30,000 years, (C) Most stable isotope - H.L. of 1,590 years

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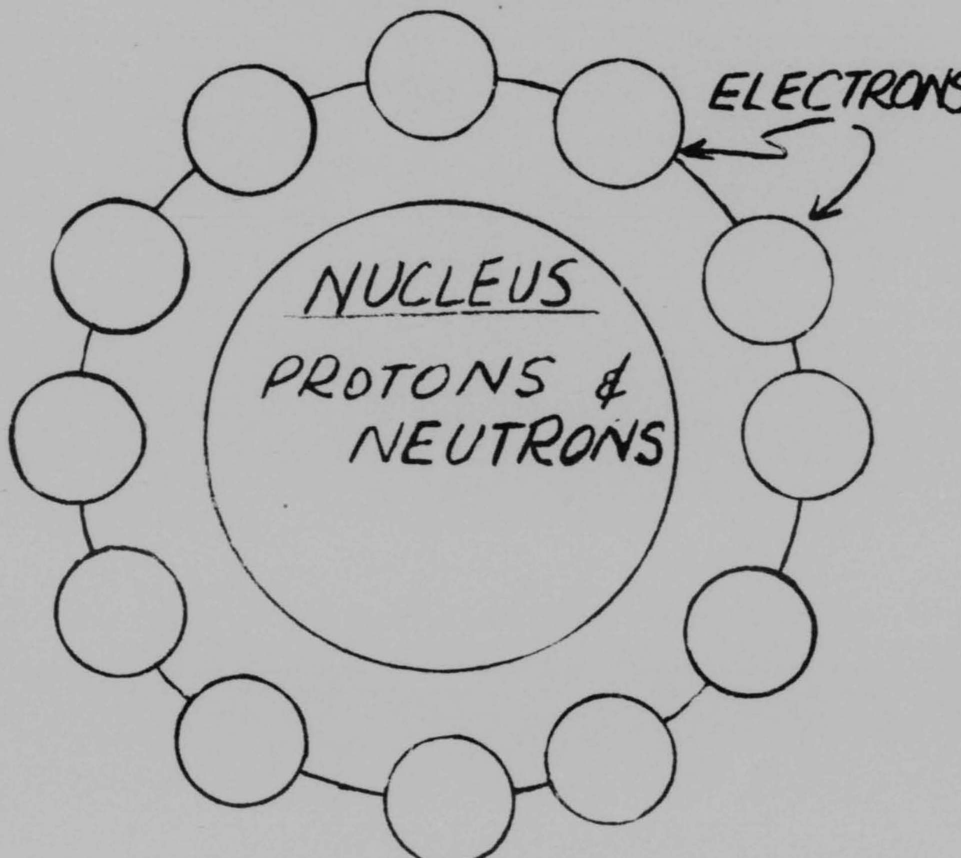
CHART 3-2



ONE ATOM

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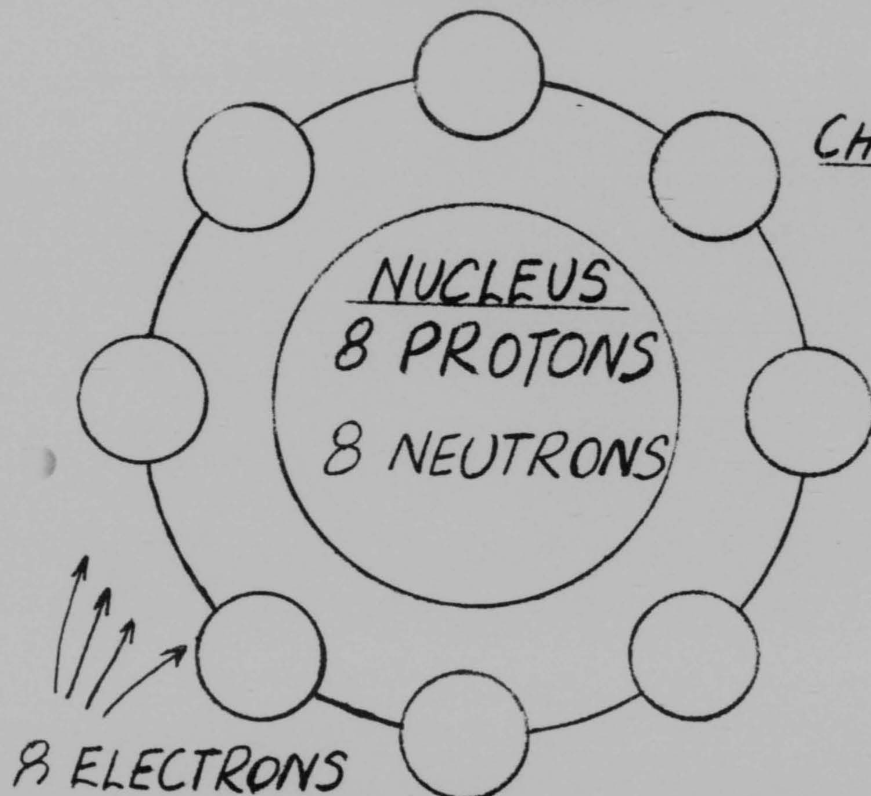
CHART 3-3



OXYGEN ATOM OF MASS NUMBER 16

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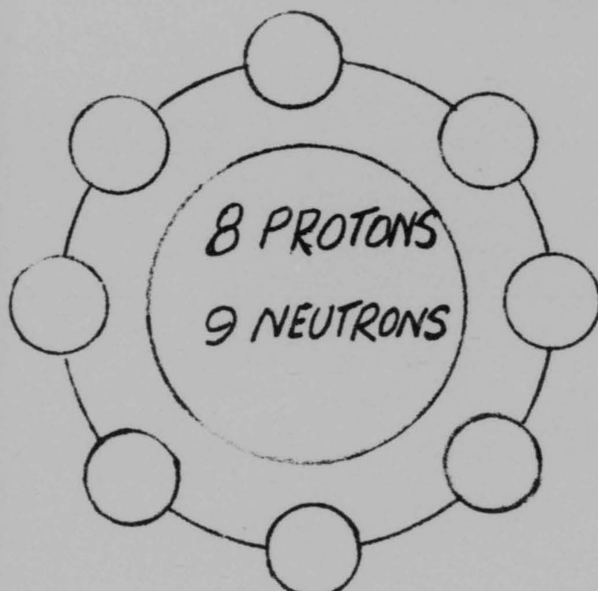
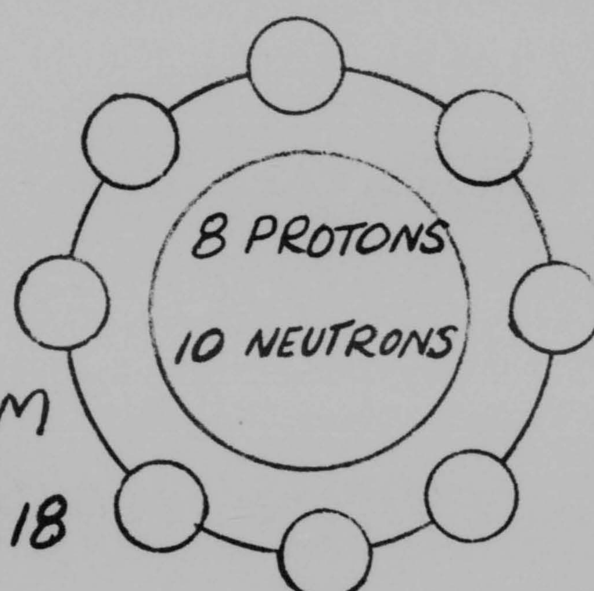
CHART 3-4



OXYGEN ATOM
OF
MASS NUMBER 17



OXYGEN ATOM
OF
MASS NUMBER 18

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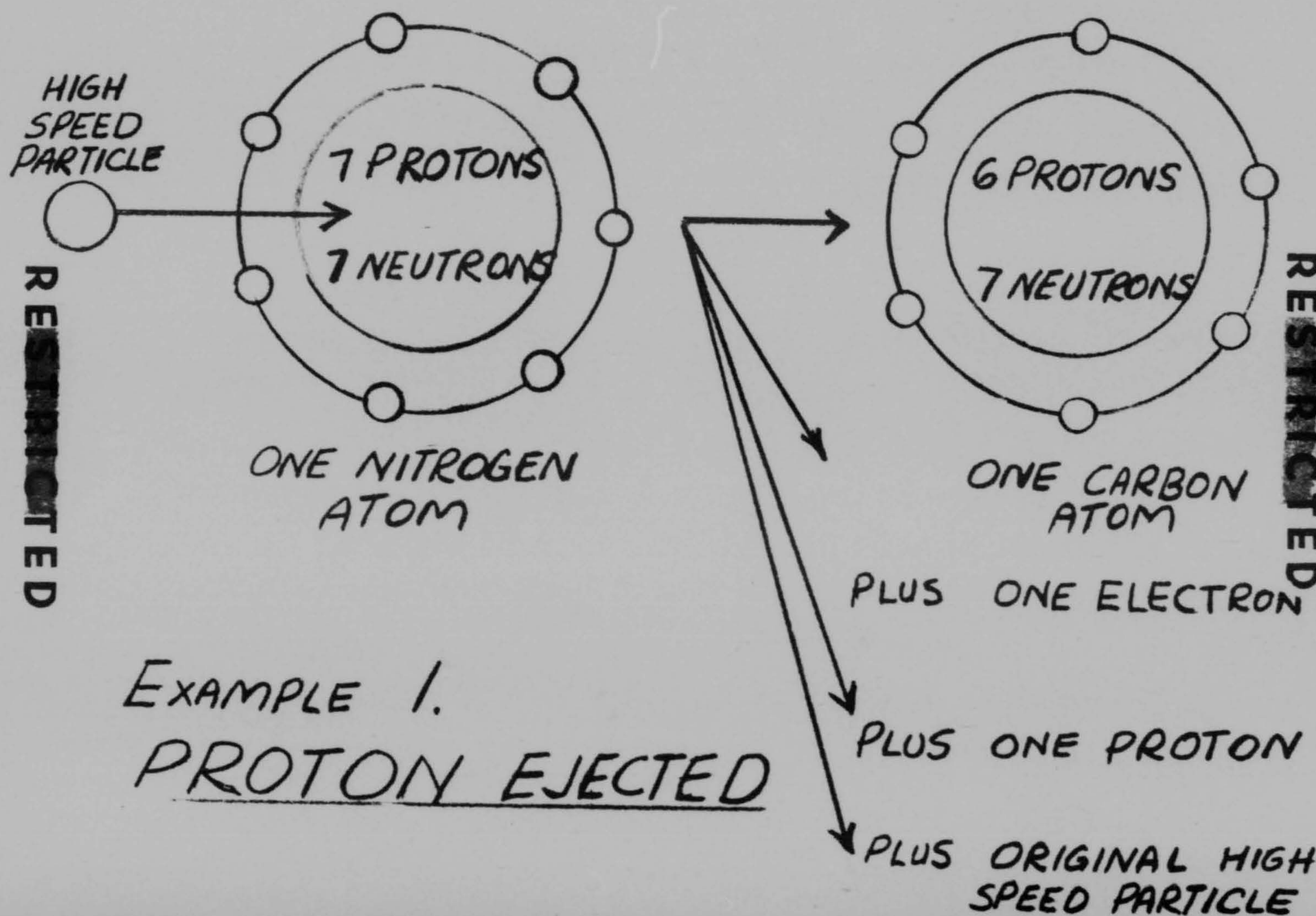
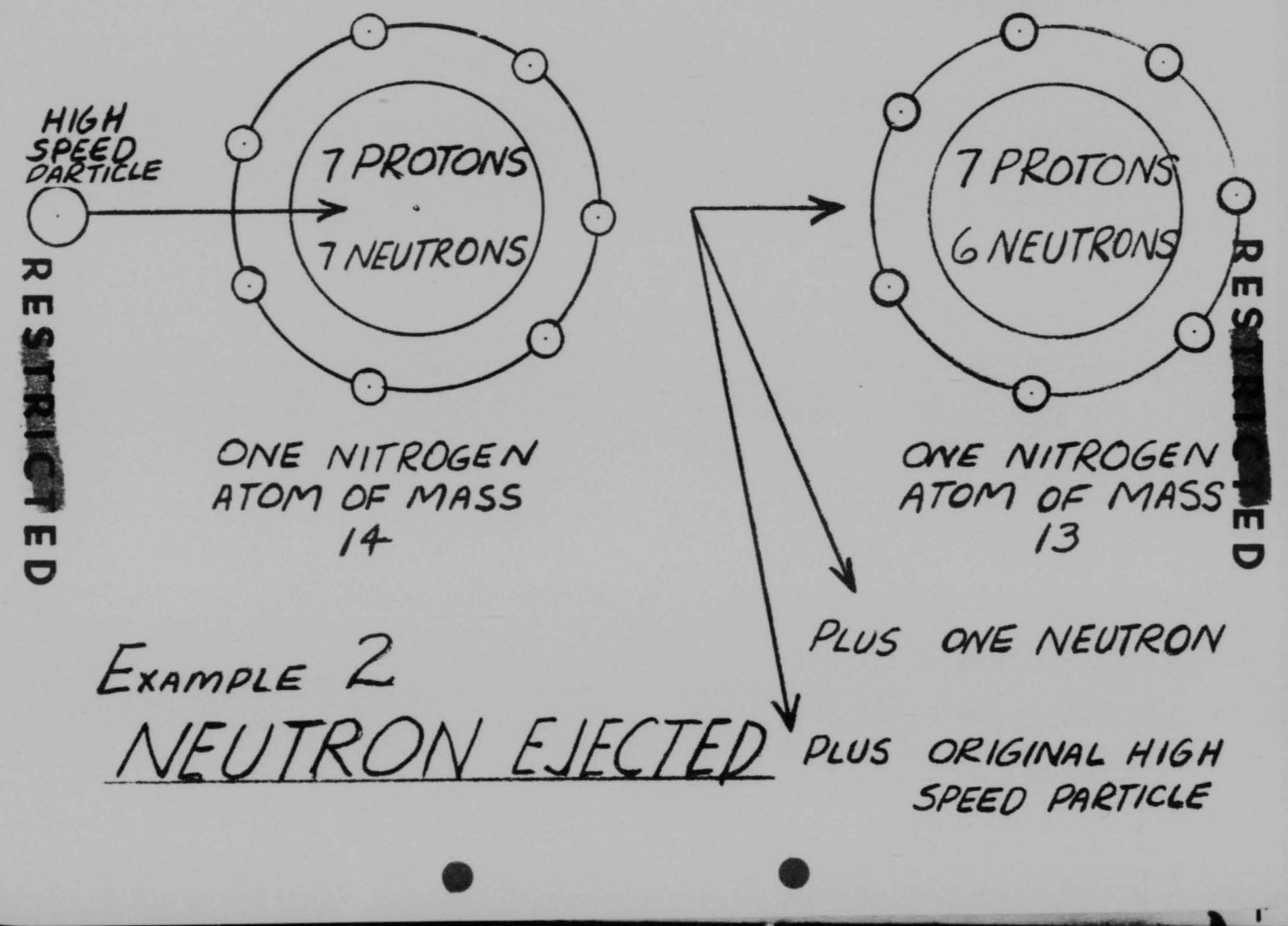
CHART 3-5



EXAMPLE 1.
PROTON EJECTED

CHART 3-6



EXAMPLE 2

NEUTRON EJECTED

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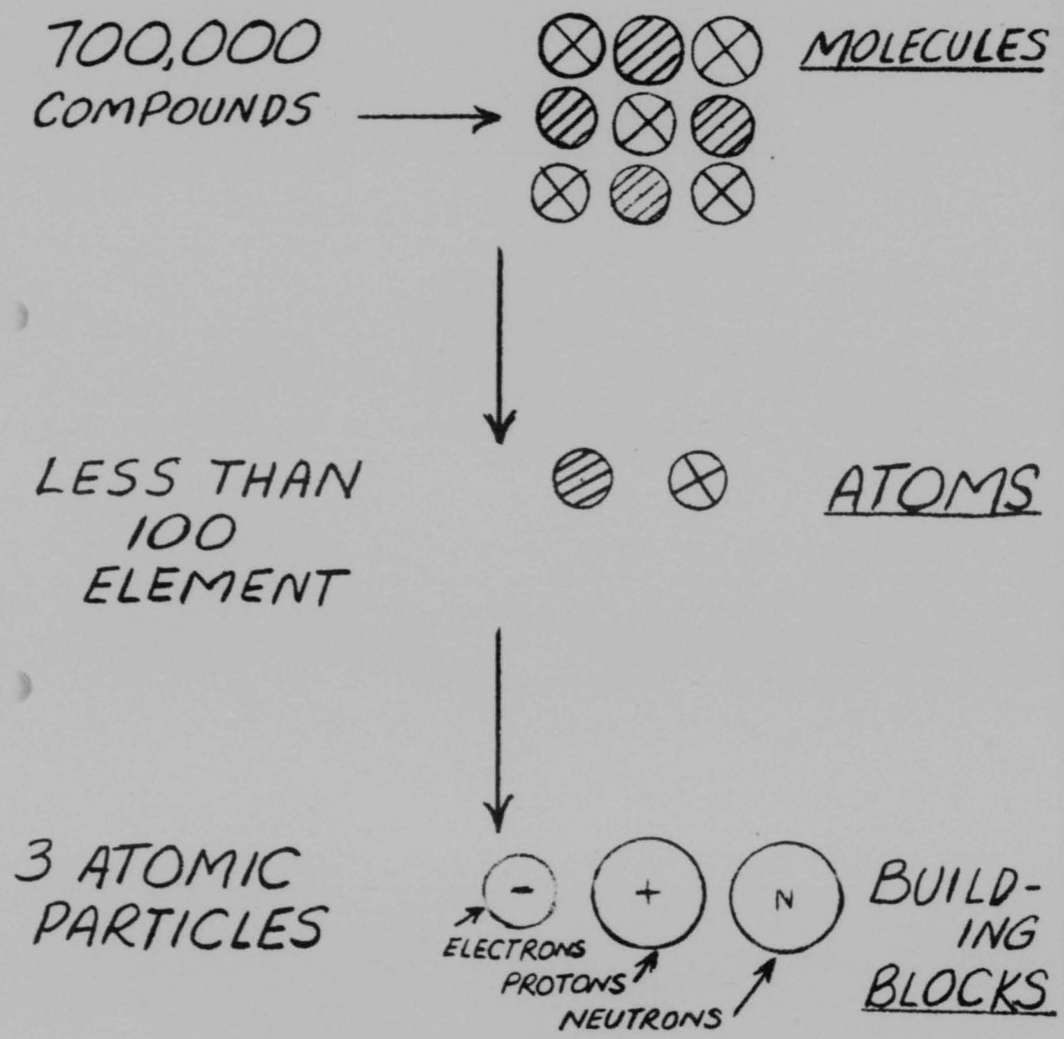
CHART 3-7



COMPOSITION OF MATTER

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TRAINING OUTLINE NO: 4

LECTURE: Electro-magnetic Radiation and Radioactivity.

TIME: Fifty (50) minutes.

PLACE: Classroom.

INSTRUCTORS' REFERENCES: Paragraph 4.01 - 5.01, 5.07 - 5.11, 6.01 - 6.09, Radiological Defense Manual, Volume 1; pages 21-25, "All Hands", 1 July 1946, Navy Department; Chapter 1, "Atomic Energy for Military Purposes", Smyth; Paragraphs 29-35, 46-51, 66-71, 53-56, 107-115, 120, "Introduction to Atomic Physics", Semat; Chapter 14, "General Chemistry", Deming. (See Footnote*)

STUDENTS' REFERENCES: Pages 21-25, "All Hands", 1 July 1946, Navey Department.

TRAINING AIDS REQUIRED: Charts appended hereto.

1. To complete the picture of atomic structure, it is necessary to look into the matter of radioactivity. This is especially important since radioactive contamination is one of the principle hazards resulting from an atomic explosion. It is of major importance because an overdose of radioactivity is just as lethal as the effects of more conventional weapons. Several terms applicable to this field must be defined.

2. Energy is the first term encountered and it may be defined as "the ability to do work". There are many forms of energy - electrical energy, heat energy and chemical energy are the best known. Chemical energy is stored in wood, coal, oil, plants and food and is released by the burning of these materials. The burning of these substances changes the chemical energy into heat energy and this heat

*The explanations in this lecture have been simplified insofar as practicable. Within the objective and scope of this course, it was felt mandatory to do so. It is encumbent on instructors to familiarize themselves thoroughly with all the basic principles of energy, work, electro-magnetic radiation, radioactivity and ionization in order that they may answer any questions presented by technically qualified students.

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energy may be used to generate electrical energy which is used to operate machines which perform work. Energy which is stored-up or which only has the ability to do work is what we call potential energy, but energy which is actually doing work, we call kinetic energy. This work being performed may not be useful at all, but some definite thing is happening which requires energy to make it happen. The importance of this point lies in the fact that a particle, of some definite mass, moving through space with some definite velocity is said to possess kinetic energy. Some of the kinetic energy which this shooting particle has is being consumed (doing work) on the air through which it is passing with the result that the temperature of the air is being increased. This loss of energy to the air is very small, however, and most of the energy is simply being transferred from the starting point of the particle to the point where it eventually strikes something and stops (figuratively "hits a brick wall"). It is therefore easy to visualize the transmission of energy by fast moving particles which give up their kinetic energy on collision with stationary targets. Less obvious, but equally true, is the transfer of energy by wave motion.

3. Wave motion is most easily explained by a consideration of radio waves. These waves are usually pictured by a snakelike diagram.

(INSTRUCTOR - REPRODUCE CHART 4 - 1)

At this time it is well to state that no one is quite sure as to what these waves are. We might ask "how do we know such waves exist?" Mathematically, their existence and properties can be determined just as we know that the "wild blue yonder" exists and has certain obvious properties, but we are no more certain of what waves actually are than we are of what the "wild blue yonder" is. Fortunately we are only interested in the effects of waves, not their composition, in this course. Let us consider wave motion as a beam of oscillating particles, composition unknown, traveling through space in straight lines with a constant velocity of 186,272 miles per second.

4. Each type of wave is distinguished by the distance between successive peaks of oscillation. This distance is known as the wave length

(INSTRUCTOR - REFER TO CHART 4 - 1)

and covers the entire scale of distance from almost zero inches to hundreds of miles. This wave motion results in the transfer of energy and so we define the transfer of energy by wave motion as electromagnetic radiation, or as it is normally called, radiation. Some of the better known forms of radiation are cosmic rays, radar waves, X-rays, ultraviolet rays, visible light rays (the different colors being due to difference in wave lengths), infra-red rays and radio waves. The following table will give you some idea of the wave lengths of these different forms.

(INSTRUCTOR - REPRODUCE CHART 4 - 2)

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The next step is to determine the amount of energy transmitted by the various forms of radiation. The shorter the wave length, the greater the amount of energy transmitted. Several analogies could be drawn to illustrate the point, one being that a ship sailing through a long, slow ocean swell (long wave length) does not take half the pounding that it does when going through a choppy sea (short wave length). Thus X-rays, which have a very, very short wave length, have a very high energy content compared to radio waves, which have a very long wave length.

5. The fact that radiation has several forms, each distinguished by its characteristic wave length, should not be allowed to confuse us on the general properties of radiation. These properties may be summed up as follows:

a. Velocity - 186,272 miles per second.

b. Visibility - invisible except in the visible light range.

c. Energy content - depends on wave length.

d. Physical perception - none, except heat in certain ranges.

e. Composition - unknown but may be thought of as oscillating particles.

(INSTRUCTOR - REPRODUCE ABOVE DATA AND QUESTION CLASS ON ITS UNDERSTANDING OF THE MATERIAL)

6. One form of radiation which is not commonly known but which we will deal with primarily is gamma radiation. Gamma radiation is most nearly comparable to X-rays but has a shorter wave length and is therefore of higher energy content.

7. On the theory that gamma radiation may be considered a beam of high energy oscillating particles (as discussed above) traveling in a straight line, the assumption is that gamma radiation is not greatly different from a beam of electrons, or protons, or neutrons or any other high energy particles. Certainly the gamma radiation is somewhat different because:

a. It travels faster.

b. It oscillates.

c. It has no detectable size or mass and normally cannot act as an atomic bullet to smash particles loose from the nucleus of an atom, but the gamma radiation IS transferring energy, and this is what we are interested in. Because of this fact, any beam of high energy particles may be considered as ionizing radiation. "High Energy Radiation" may be defined as any ionizing radiation which con-

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tains enough energy to cause bodily harm.

8. The element Uranium has a most unusual property in that the atoms of Uranium spontaneously give off energy. This is not a freak case, however, since several other elements such as radium, thorium and radon do likewise, but we will consider the case of Uranium as typical.

9. Radioactivity is the term applied to the process wherein certain atoms emit energy spontaneously. The nature of this radioactivity was established after much research and found to be threefold in composition:

a. Alpha particles traveling at high velocities.

b. Beta particles traveling at very high velocities.

c. Gamma radiation traveling at the speed of light.

All three of these components fall under our definition of high energy radiation and thus radioactivity is high energy radiation.

10. An alpha particle is the nucleus of a helium atom, containing 2 protons and 2 neutrons very firmly bound together. These alpha particles have an initial velocity of about 1/10 the speed of light and possess great kinetic energy but have little penetrating power due to their relatively large size.

11. The beta particle turned out to be nothing but an electron in different form. There is a difference between beta particles and electrons as concerns their origin. Beta particles originate in the nucleus, while electrons are outside the nucleus. Beta particles have an initial velocity of about 99% of the speed of light and possess substantial amounts of energy. Because of their small mass, although not because of smaller size, beta particles have much greater penetrating power than do alpha particles.

12. Gamma radiation is true electromagnetic radiation traveling with the speed of light, is quite energetic and has enormous penetrating power.

13. Some idea of the relative penetrating power of these particles is shown by the following diagram.

(INSTRUCTOR - REPRODUCE CHART 4-3)

14. It is beyond the scope of this course to explain why certain elements found in nature spontaneously emit energy. The simplest idea that can be presented is to say that at the instant of formation of a radioactive atom, that atom was forced to store up more energy than was required to bind the protons and neutrons together. The excess energy

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is not needed and therefore escapes as fast as it is possible to do so. When non-radioactive elements are split or fissioned in the laboratory the energy balance of the remaining nucleus is always slightly "out" and the nucleus becomes artificially radioactive. The same escape procedure immediately starts to function. In elements which are naturally radioactive the escape procedure is very slow, requiring many thousands of years to complete. In elements which are made artificially radioactive the escape procedure is relatively fast and may be completed in from a fraction of a second to a few years.

15. This escape procedure is called "Radioactive Decay" and the rate at which it occurs is called the decay rate. If we take 1000 radioactive atoms of an element, A, and examine the decay process, we will find that after some definite period of time, half - or 500 - of these atoms will have completely decayed and will have changed into some different element, B. Assume that this requires one hour. We now have 500 radioactive atoms of element A left. At the end of the second hour, we will have 250 radioactive atoms of element A left and so on, as shown by the following table.

At the End of		Radioactive Atoms of Element A Left
Start	-	1000
1 hour	-	500
2 hours	-	250
3 hours	-	125
4 hours	-	63
5 hours	-	32

(INSTRUCTOR - REPRODUCE ABOVE TABLE)

It is apparent that each hour, one-half of the remaining radioactive atoms are decaying to a different isotope. The time that it takes for one-half of the radioactive atoms of an element to decay is called the "half-life". Each radioactive isotope has a characteristic half-life of its own and no two are the same. These half-lives cover an enormous range of time - from a fraction of one second to thousands of years. The military significance of this will be brought out later.

16. Finally it is necessary to discuss the process known as "ionization" in order that the methods used for the detection and measurement of high energy radiation may be understood. A series of charts will help in an understanding of this process.

17. Ionization is a process in which orbital electrons, of atoms, are struck by high energy radiation passing through their orbits, and,

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as a result of these collisions, the orbital electrons are ejected from their orbit.

(INSTRUCTOR - SEE CHART 4-4)

18. These ejected electrons fly over to an adjoining neutral atom and arbitrarily attach theselves. This causes the neutral atom to become negatively charged (the electron is a negative charge of electricity) and leaves the atom from which the electron was ejected, positively charged due to the protons in the nucleus.

(INSTRUCTOR - SEE CHART 4-5)

19. At the conclusion of these two steps Atoms A and B are said to be ionized. This is important since these ionized or electrically charged atoms can be effected by magnetic fields whereas neutral atoms cannot.

20. High energy radiation is capable of ionizing all material through which it passes. To ionize this material, however, takes energy and the incident high energy radiation if finally stopped or absorbed when it loses all of its kinetic energy. Thus an alpha particle causes heavy ionization but only travels a short distance since it loses energy very fast; a beta particle causes lighter ionization but travels farther since it loses energy more slowly; and gamma radiation which causes still lighter ionization travels quite far, because it loses energy very slowly. Neutrons are also a form of high energy radiation and are comparable to gamma radiation in penetrating properties.

Are there any questions?

INSTRUCTOR'S QUESTIONS

1. What is energy?

2. What distinguishes one type of wave from another?

3. What determines the amount of energy transmitted by waves?

4. What may gamma waves be considered similar to?

5. What is high energy radiation?

6. Name four particles which may be found in high energy radiation?

7. What is the relative penetrating power of alpha particles, beta particles and gamma radiation?

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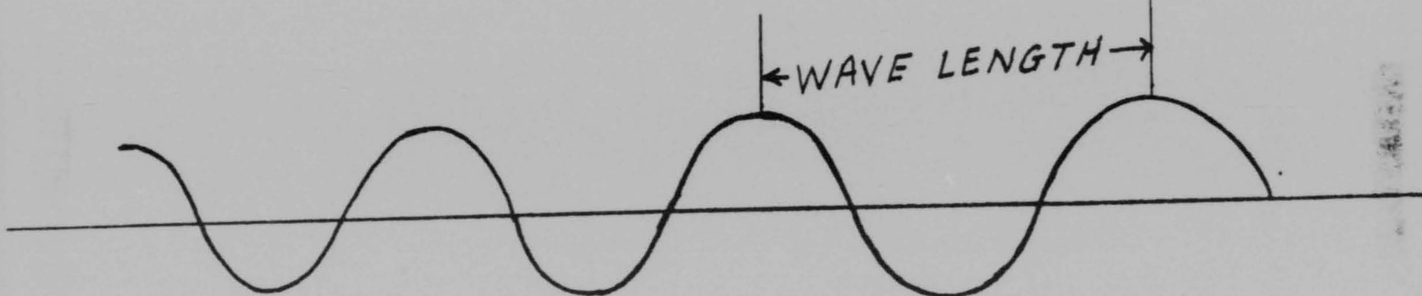
CHART 4-1



WAVE MOTION

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CHART 4-2

WAVE LENGTHS OF ELECTRO-MAGNETIC RADIATION

Type	Wave Length
Electric Waves	600 miles
Long Radio Waves	10.7 miles
Broadcast Radio Waves	1.9 to 3.5 miles
Short Radio Waves	3 to 32 feet
Ultra Short Radio Waves	4 inches to 3 feet
Radar Waves	.003 inches
Heat and Infra-Red Waves	.00003 to .012 inches
Visual Light Waves	.00001 to .00003 inches
Ultra-Violet Waves	.0000001 to .00001 inches
X-Rays	.0000000001 to .0000001 inches
Gamma Rays	.000000000001 to .000000001 inches
Cosmic Rays	less than gamma

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CHART 4-3

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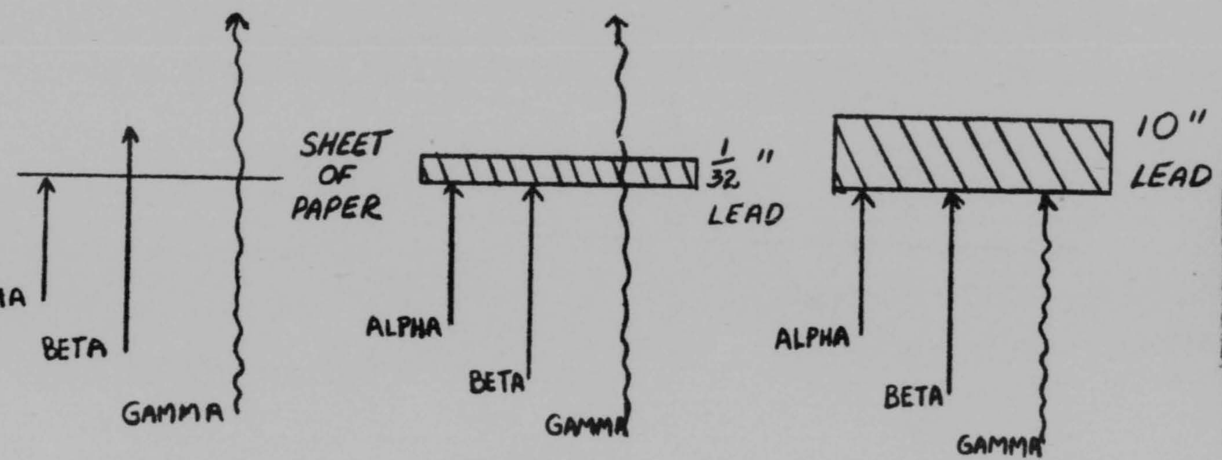

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PENETRATING POWER OF RADIOACTIVITY

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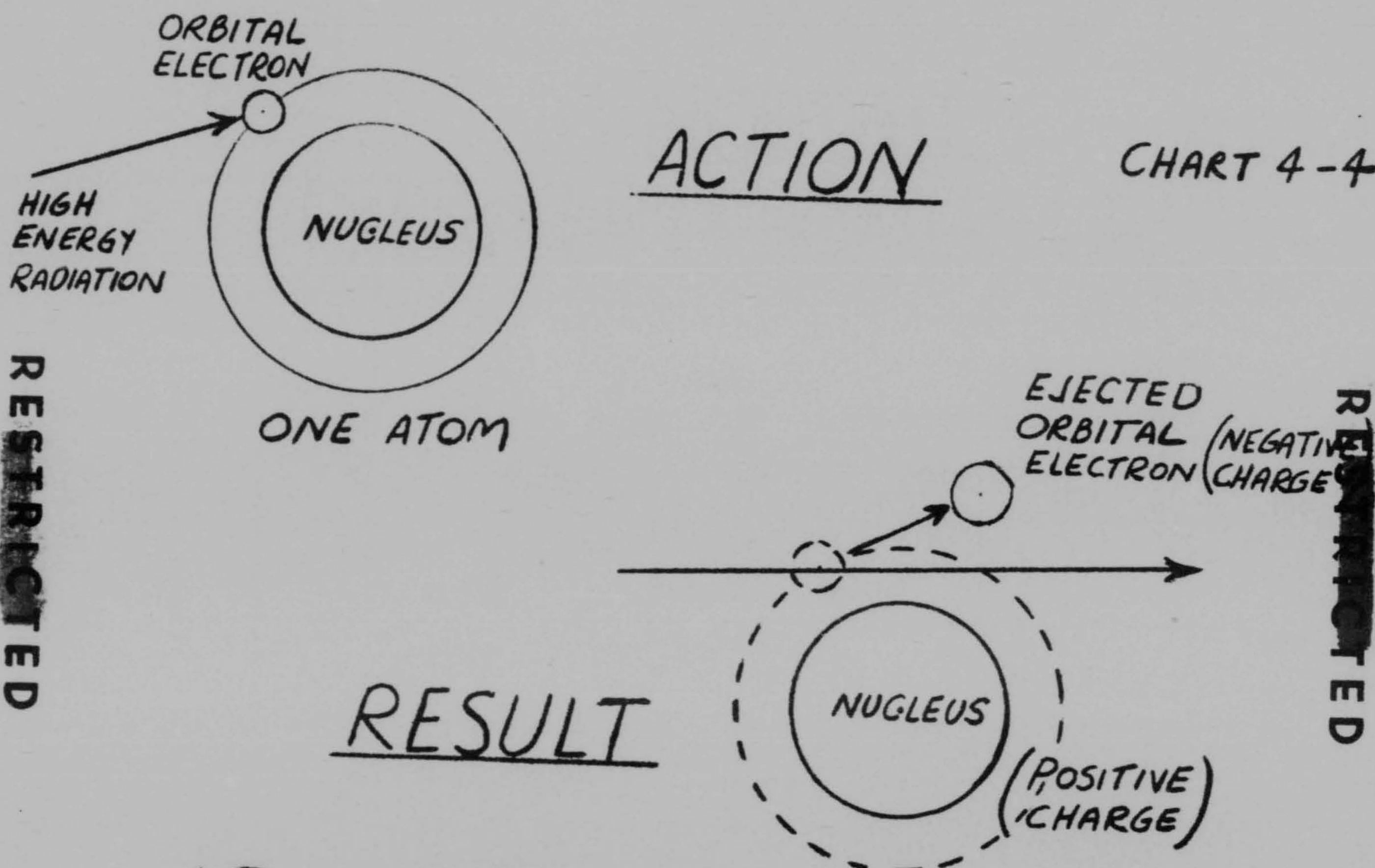
CHART 4-4



IONIZATION – STEP ONE

CHART 4-5

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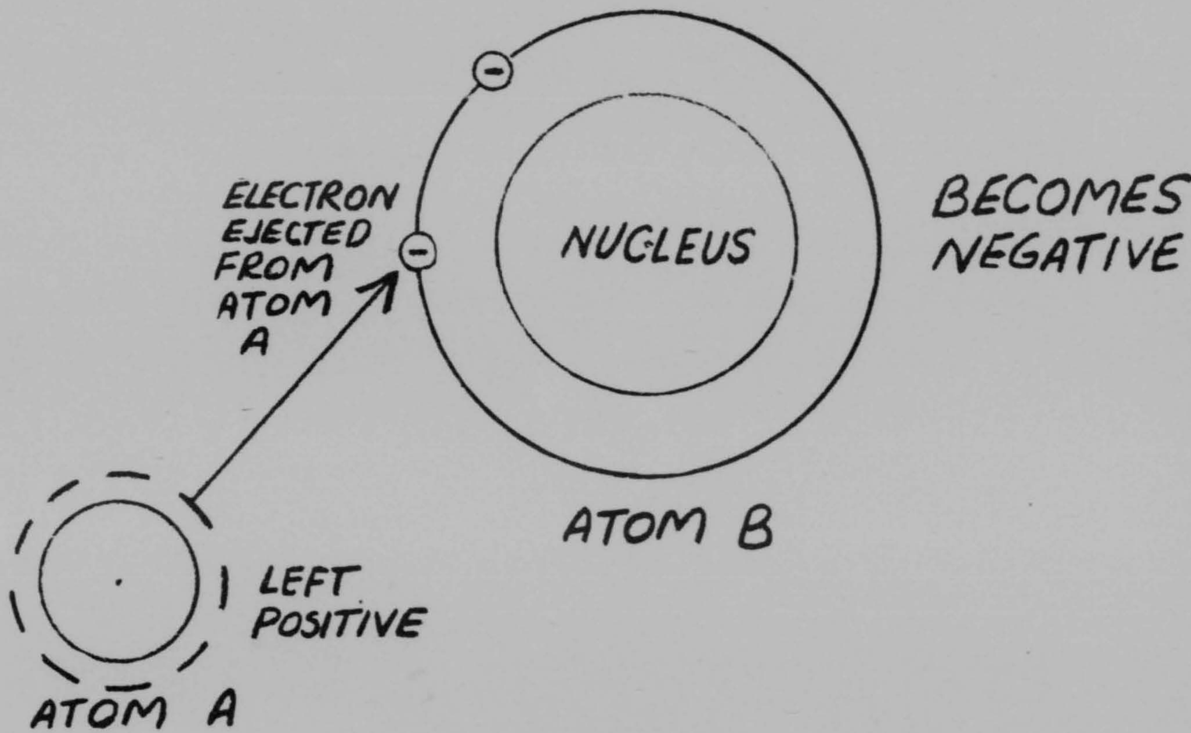

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IONIZATION - STEP TWO

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TRAINING OUTLINE NO: 5

LECTURE: Nuclear Reactions, Atomic Fission and Chain Reactions.

TIME: Fifty (50) minutes.

PLACE: Classroom.

INSTRUCTORS' REFERENCES: Paragraphs 7.01 - 8.14, Radiological Defense Manual, Vol 1; Pages 24-47, "All Hands", 1 July 1946, Navy Department; Chapters II, IV, VI, VIII, XII, "Atomic Energy for Military Purposes", Smyth; Paragraphs 115-126, 127, 133, 135-145, "Introduction to Atomic Physics", Semat.

STUDENTS' REFERENCES: Pages 24-47, "All Hands", 1 July 1946, Navy Department.

TRAINING AIDS REQUIRED: Charts appended hereto.

1. The preceding two periods have been devoted to a study of atomic structure, electro-magnetic radiation and radioactivity. These phenomena are essential to an understanding of nuclear reactions, atomic fission and chain reactions.

2. Nuclear reactions may be thought of as changes in the nuclei of atoms. These changes are brought about by firing a "bullet" into a target nuclei. Either neutrons, protons, alpha particles or beta particles may be used for "bullets" depending on what type of change is required. A variety of types of nuclear reactions are known; the more important ones being:

a. Reactions induced by neutrons.

b. Reactions induced by protons.

c. Reactions induced by alpha particles.

d. Reactions induced by electrons.

e. Reactions induced by electro-magnetic radiation.

3. Neutron reactions are of paramount interest because neutron "bullets" are used to "break-up" uranium atoms and thereby cause an atomic explosion. In addition neutron reactions are responsible for certain additional hazards following an atomic explosion.

4. Proton reactions are of interest because, due to their wide

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variety, they make possible all sorts of "building" in the field of nuclear chemistry.

5. Reactions induced by alpha particles, beta particles and electro-magnetic radiation are of value in the field of nuclear research and do not greatly concern us. At this point it is well to point out that we are not speaking about the effects which neutrons, protons, alpha particles, electrons and electro-magnetic radiation produce in the human body. The physiological effect of high energy radiation is due to ionization of tissue (a process involving orbital electrons of the atoms in our flesh, bones and blood) and not to changes within the nuclei of body atoms.

6. Two general types of neutron induced reactions are worth additional study. These are:

a. Simple neutron capture. In such reactions, the target nucleus "captures" the neutron "bullet". This serves to increase the target nucleus's mass (atomic weight) but leaves its atomic number (and therefore, chemical properties) unchanged. The effect is to produce a heavier isotope of the element being bombarded. An isotope produced in this manner is usually radioactive and therefore dangerous to personnel. The military significance of this type of reaction is apparent when it is understood that a neutron flux or "hail" occurs in the vicinity of an atomic detonation. This flux bombards everything within its range, over 1000 yards, and induces radioactivity therein.

b. Neutron capture with particle emission. This type of reaction may be thought of as an atom smashing reaction. A neutron "bullet" strikes the target nucleus and knocks something out. In the majority of cases, this is a one-time affair which begins with a neutron hitting the nucleus and ends with a proton, or alpha particle being ejected from the nucleus. A few rarer cases exist where TWO neutrons are ejected from the target nucleus. Finally a half-dozen very rare cases are known where MORE THAN TWO neutrons are ejected. This last case is very interesting indeed since we, so to speak, get more than "two for one" and the chances of running a non-stop neutron parlay are better than "sporting". In effect this means a reaction, wherein more bullets come out than were put in, will continue once started. Factors beyond the scope of this course are present which prohibit most of these incipient chain reactions from developing but two isotopes, U235 and Pu239 will do so. Nuclei of these two isotopes, when struck by a neutron bullet split into approximately two equal parts, eject more than two neutrons which were left over as spare parts and liberate a large amount of surplus energy (considering the amount of material involved). This is the fission reaction which makes possible an atomic weapon.

(INSTRUCTOR - REPRODUCE CHART 5-1)

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The ejected neutrons are very important and are the key with which we unlock atomic energy. This is possible because they are expelled with sufficient force to act as new bullets and cause the fission of more than one additional U235 or Pu239 atom. The manner in which this reaction may build up is shown on the following chart and this is what we call a chain reaction.

(INSTRUCTOR - REPRODUCE CHART 5-2)

7. There are many complicating factors in the production of U235 and Pu239 on a scale large enough for use in atomic weapons. One of these factors is the absolute purity to which the isotopes must be refined. Another is the scarcity of material; U235 being generally present only to the extent of 1 part in 140 parts of natural uranium, while Pu239 must be made in piles from U238 one atom at a time, a task that staggers the imagination as to its difficulty, expense and amount of equipment required.

8. In order to cause a chain reaction, quite a large quantity of fissionable material must be used. If a small quantity of material is used, most of the neutrons escape through the surface of the material and the reaction stops. The relatively large ratio of surface area to volume in a small geometric solid allows this neutron escape. If you have a somewhat larger quantity, however, the neutrons produced by the first atom splitting cannot fly out of the mass. They split more atoms, these produce more neutrons and split more atoms and so on until an explosion may occur due to the sudden release of energy. The size at which the Uranium mass is just large enough to sustain the chain reaction is called the critical mass. Less than that mass will not sustain a chain reaction because practically all the neutrons produced by fission escape through the surface area without causing additional fission. More than critical mass will sustain a chain reaction since almost all of the neutrons produced by fission will cause additional fission. It is important to understand that there are many stray neutrons in the air and any one of these stray neutrons will start a chain reaction in a greater than critical mass.

9. Whether or not there is an explosion depends on whether the chain reaction develops in a short enough time. If the mass of fissionable material is made strongly over-critical in size the chain reaction develops very rapidly. Energy is then released at an explosive rate and the fissionable material expands until it becomes diluted; with dilution more neutrons escape through the surface area and the reaction stops. But before this expansion stops the reaction, a tremendous quantity of energy is released and a violent explosion results. This is how the atomic bomb works. So your bomb might look like this:

(INSTRUCTOR - REPRODUCE CHART 5-3)

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10. A question at this point might be, "Why doesn't the bomb blow apart and the explosion stop before it gets any greater in violence than that resulting from a hand grenade?" One answer lies in the fact that nuclear reactions occur in very short intervals of time. One generation of neutrons will cause fission of uranium atoms in about one hundred millionth of a second. Each successive generation of neutrons will be twice as large in number as the previous generation of neutrons and this means that if we started with 2 neutrons and doubled the number for 100 successive times we would fission a fantastic number of uranium atoms with the 100th generation of neutrons. This would liberate a very large amount of energy and the entire process would occur in about one millionth of a second - a very short time indeed. By placing a heavy tamper or shield around the bomb it is possible to hold it together for a few additional millionths of a second and this additonal increment of time means the difference between a small explosion and a very large one.

11. Natural Uranium consists of three isotopes; U-234, U-235 and U-238, which are present to the extent of 0.006%, 0.7% and 99.3% respectively. Uranium ore is very scarce, and, if we use only the isotope U-235, less than 1% of this scarce ore can be utilized. Obviously it is desirable to find some method whereby the U-238 isotope can be used and thus all but a fraction of the ore utilized.

12. Under certain conditions U-238 can be made to fission but these conditions are such that they make the use of U-238 in a bomb impracticable. However, it is possible to make a new element, Plutonium, from the U-238 and Plutonium makes an excellent material for bombs. One manner in which this might be accomplished is illustrated by the following chart:

(INSTRUCTOR - REPRODUCE CHART 5-4)

13. Students will not be held responsible for knowledge of these reactions, and they are only shown as a matter of interest. The vast Atomic Energy Commission plants at Hanford, Washington, called piles, are used for the production of Plutonium.

Are there any questions?

<u>INSTRUCTOR'S QUESTIONS</u>:

1. What three things happen when an atom of U-235 fissions?

2. What limits the availability of atomic energy?

3. Why is it necessary to produce Plutonium?

4. Can small atomic bombs be made? If so, why do we not use them? If not, why not?

5. What is meant by the term critical mass?

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6. What is the effect of making a bomb much larger than critical in size?

7. What are two types of neutron induced reactions?

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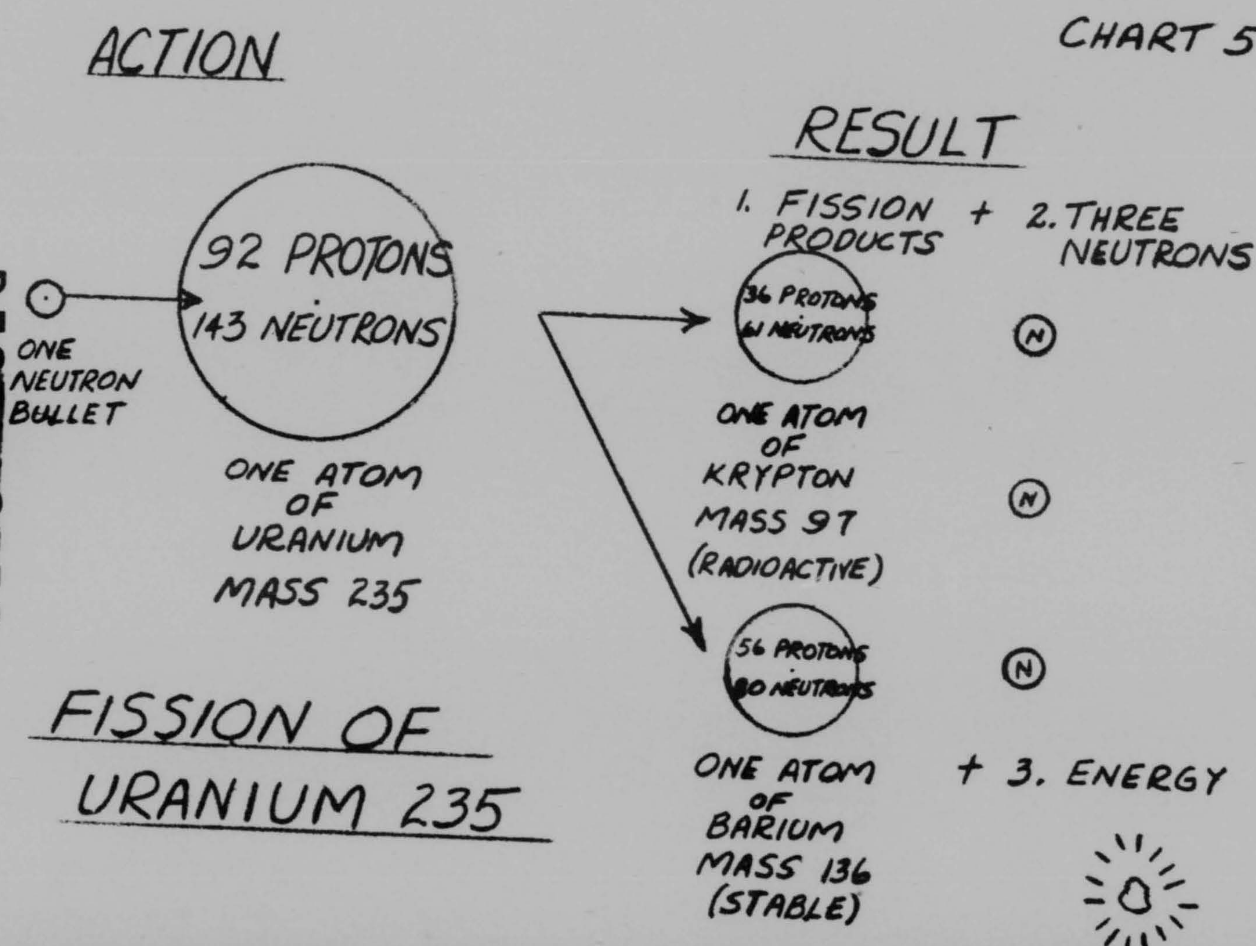

FISSION OF URANIUM 235

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CHART 5-2

CHAIN REACTION

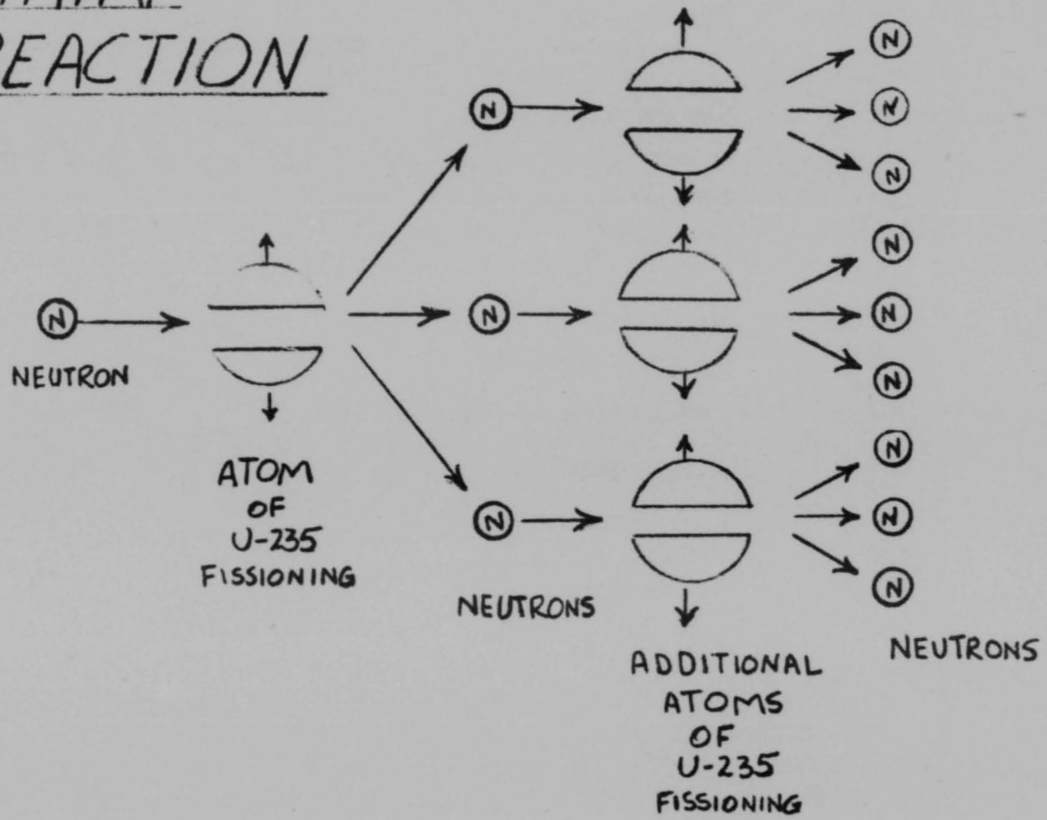

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CHART 5-3

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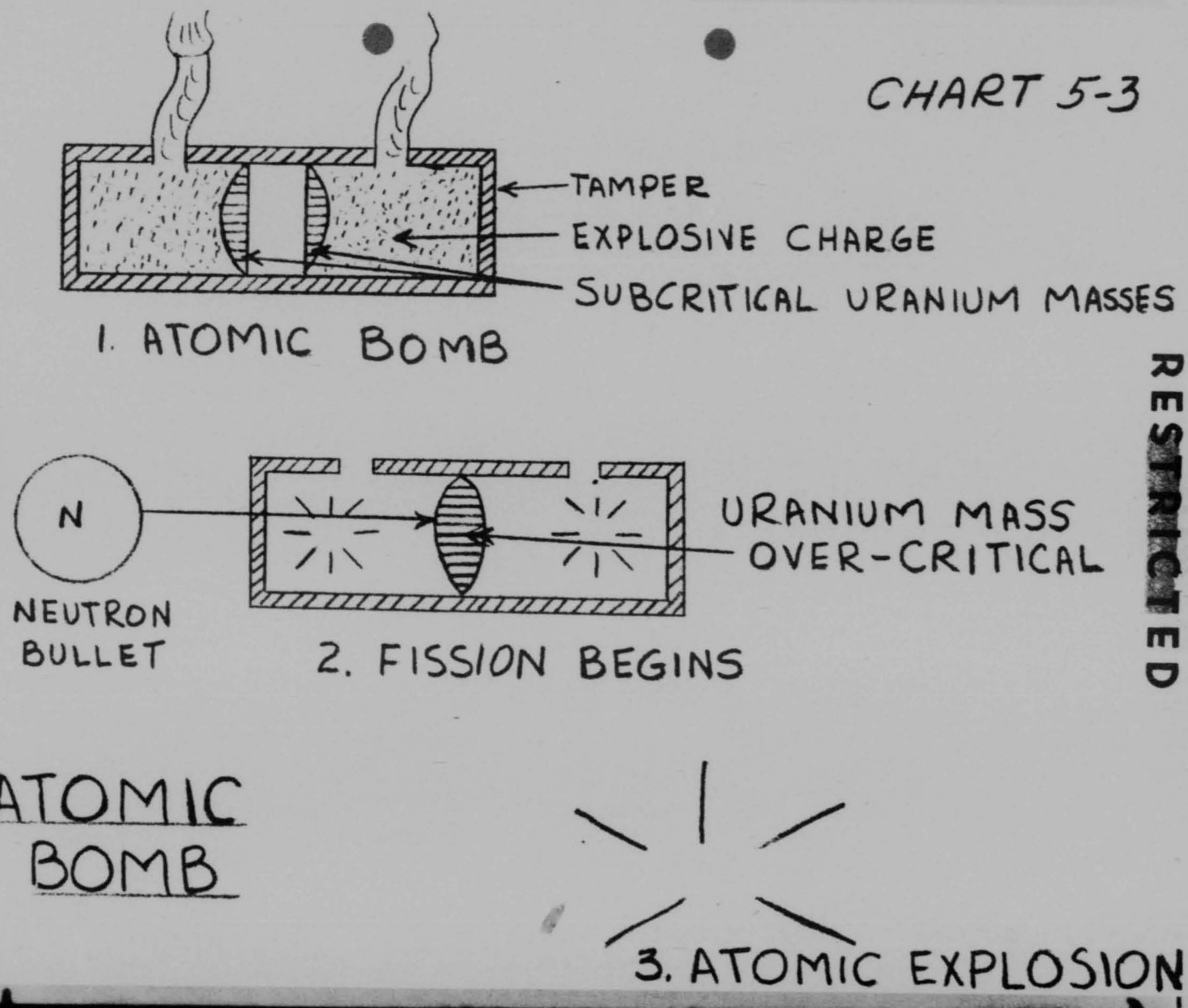

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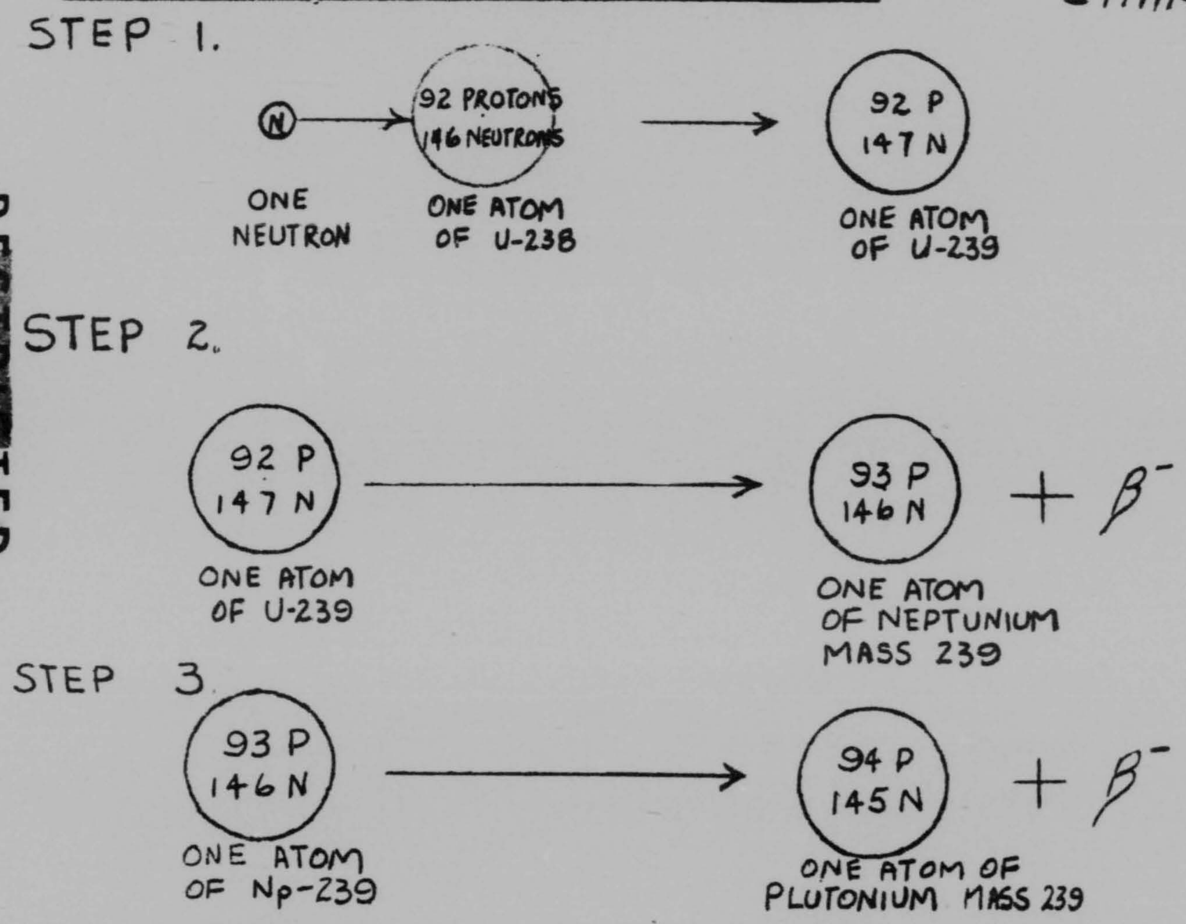
ATOMIC BOMB

PLUTONIUM PRODUCTION

CHART 5-4



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TRAINING OUTLINE NO: 6

LECTURE: Explosion Phenomena.

TIME: Fifty (50) minutes.

PLACE: Classroom.

INSTRUCTORS' REFERENCES: Pages 3, 44 - 47, "All Hands", 1 July 1946, Navy Department; Chemical Corps School Mimeographs No. 21 and No 202; "Medical Aspects of Nuclear Energy", Armed Forces Special Weapons Project, National Military Establishement, 1949.

STUDENTS' REFERENCES: None.

TRAINING AIDS REQUIRED: Projector, Screen, Film "A Tale of Two Cities" (ANSM 74). Charts as noted in text.

1. Thus far this course has been concerned with what an atom is, what radioactivity is, what is meant by a chain reaction, and the principle of the atomic bomb.

2. This talk on "Explosion Phenomena" will give an account of what goes on in an atomic explosion and discuss the hazards that exist during and after atomic explosions.

3. Certain people have stated publicly that the atom bomb is "just another big bomb". The A-bomb cannot be dismissed that simply. No other bomb known can send invisible rays through reinforced concrete to kill personnel taking shelter there and no other single bomb can effectively wipe out a modern city.

4. Comparing the HE and the atomic explosion will provide some interesting material. The characteristics of the HE explosion are well known. The HE explosion is a chemical reaction. This reaction, which proceeds with great velocity is set up in the body of the explosive and converts a small volume of solid material into great quantities of heated gases. Due to the temperature and pressure of the generated gas, a shock wave is set up in the air, or other surrounding medium. The energy expended in this manner is quite large per pound of the explosive, but it is trivial, perhaps only a millionth part of the energy developed by the same amount of uranium or plutonium.

5. The shock wave which is set up in the air by an explosion, whether due to HE or to an atomic explosion, moves outward from the

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center of the explosion with a velocity which is generally greater than the speed of sound. This wave is a compression wave in the air. Normal air pressure is about 15 pounds per square inch. In the shock wave, two conditions exist. There is a region in which the air pressure is greater, by quite a few pounds per square inch, than normal air pressure. Then there is a second region in which the air pressure is a pound or two lower than normal. These two regions constitute the shock wave. The greater the intensity of the explosion, the greater the increase in the positive part of the shock wave, and the lower the pressure in the negative region. Also, the more powerful the explosion, the greater the velocity with which the shock wave moves outward from the point of the explosion.

(INSTRUCTOR- REPRODUCE CHART 6-1)

6. Assume that instruments to measure air pressure are set up at some distance from the point at which several pounds of HE are to be exploded. The explosion develops the shock wave which moves outward and crosses the position of the recording instruments. These instruments will show an increase in pressure which is followed immediately by a decrease in pressure. It is this negative pressure which blows out windows and often causes the collapse of structures that survived the original positive shock. The positive shock wave lasts for about one millionth of a second, and this is followed by the negative pressure which lasts for about three millionths of a second. Thus, the shock wave for the HE explosion comes as a sharp blow or pulse of pressure increase followed by a pressure decrease. Finally, as the shock wave travels outward, its intensity falls off until it finally vanishes.

7. The atomic bomb explosion also produces a shock wave which has much the same characteristics as does the HE wave. Since the atomic explosion is far more intense it could be expected that the shock wave which accompanies it should show a higher pressure in the positive phase, and a lower pressure in the negative phase. Also the shock wave should travel at a far higher rate of speed for the atomic explosion. This is exactly what is observed. The positive phase of the atomic shock wave may show increases in pressure which are several times the increase for the HE explosion. The duration of the positive wave may last for one tenth of a second, which is 100,000 times as long as that of the HE explosion. It can be stated that if the positive phase increases the normal air pressure by five pounds per square inch, the shock wave will be most destructive. There are 144 inches to the square foot, and if a positive wave of five pounds per square inch strikes the wall of a building, it means that every square foot of surface of the building on the side facing the explosion would be subjected to a force of 144 x 5 = 720 pounds. Further, this pressure would persist for about one tenth of a second.

8. If you assume that a small building, eight feet high and ten feet long stands facing the point at which an atomic explosion takes

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place, the total force against this side of the building would be (8 x 10) x 720 or about 29 tons on that small surface alone. It is easy, then, to see why most buildings will not withstand the shock wave due to the atomic explosion if they are located anywhere near the blast. Thus, at Hiroshima multi-stoned brick buildings were severly damaged if they were within a radius of one mile from the point of the explosion. Even modern reinforced concrete buildings were severely damaged if they were within a radius of 2,000 feet from the point of the explosion. These concrete buildings were designed to be earthquake proof, which required them to be more shock resistant than comparable buildings in the United States.

9. In any explosion, there is a reflection of the shock wave from solid surfaces, and the reflected waves reinforce the primary wave. It looks like this:

(INSTRUCTOR - REPRODUCE CHART 6-2)

and a reinforcing effect is brought about. This effect, called blast reflection, is well known in HE explosions, but its reinforcing effect in the atomic bomb burst is even more pronounced.

10. Up to this point, little new has been mentioned concerning the effect of atomic explosions. That is, the shock wave develops for this type of explosion about as it does for the HE explosion. It is true, of course, that the shock wave is more intense, by a factor of thousands, and is therefore, far more destructive; but the mechanism by which the shock wave is developed is the same as for the HE explosion.

11. However, as was pointed out earlier, the atomic explosion is accompanied by radiation effects which are entirely missing from the HE explosion. These effects can be divided into two groups. The first consists of those radiations which accompany the actual explosion of the bomb, and the second group those which linger or persist after an explosion.

(INSTRUCTOR - REPRODUCE CHART 6-3)

The radiation accompanying the explosion can be classified as follows:

a. Electro-magnetic radiation.
b. Neutron flux.
c. Beta radiation.
d. Alpha radiation.

12. The electro-magnetic radiation can further be sub-divided into visible light, ultra-violet, infra-red and gamma radiation. The ultra-violet is the same ultra-violet radiation which is found in sunlight. It has the same effect upon the skin; that is, it produces sunburn. This burn can be severe enough to kill. Any light weight shielding material is sufficient to protect against the ultra-violet radiation.

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13. The visible light radiation is responsible for the blinding flash of light which occurs. The intensity of this flash is many times more brilliant than the sun and, at worst, may cause injury to the eyes. At best it causes only temporary blindness.

14. The infra-red radiation is heat radiation. That is, it is the infra-red portion of the sun's spectrum which transmits most of the heat. This radiation is very intense in an atomic explosion. It can set fires at considerable distances. It will produce flash burns on exposed skin tissue at considerable distance from the explosion. Shielding will give considerable protection. It was found at Hiroshima that individuals who were exposed to the infra-red radiation and who were wearing light colored clothing escaped flash burns while those who wore dark clothing received severe burns. It was also noticed that loosely fitted clothing gave more protection than did tight clothing.

15. The gamma radiation has the same general characteristics as does X-ray radiation. However, it is more energetic and it will penetrate greater thicknesses of shielding materials. It was estimated that, at the instant of the Baker explosion at Bikini, the gamma radiation was equivalent to that of several hundred tons of radium. Since the world supply of radium is measured in pounds this is truly an astronomical figure. Light weight shielding affords no protection. Gamma radiation is not completely stopped by any amount of shielding. All the shielding does is to reduce the intensity of the radiation. Thus, if the shielding is heavy enough and the energy level of the radiation is not too intense, the individual does not receive enough radiation to cause serious effects. It was estimated that, at Hiroshima, twenty-four inches of concrete would have been sufficient to protect an individual at a distance of one mile from the explosion. For nearer points, the thickness of concrete would have to be greater. Five inches of compact clay will reduce the intensity of the gamma radiation by about one-hafl, but the initial intensity is so great that the intensity must be reduced by nearly 100 per cent if the individual is to escape fatal injury. It is to be noticed that if five inches of clay reduces the intensity by 50 per cent, then 10 inches will reduce the intensity by 75 per cent and 15 inches will reduce the intensity by 87.5 per cent. In general the heavier materials are the most efficient in reducing the intesity of gamma radiation. Thus less thickness of lead shielding would be required than would be the case for paper or wood. The walls of a wood house would afford excellent protection against ultra-violet and infra-red radiation but almost none against the gamma radiation.

16. The neutron has been mentioned in an earlier lecture. It was also mentioned that the neutron causes the fission of uranium and plutonium and that neutrons are ejected from nuclei when they undergo fission. These fission neutrons are high energy neutrons and they can penetrate great thickness of matter. Thus, at Bikini, neutrons penetrated the steel bulk-heads of ships and induced radioactivity in table salt and soap chips in the galleys. The neutron itself can cause harmful effects in the human body, but it also acts in another way. It will induce radioactivity in many substances. Thus at Bikini, and expecially in the Baker test, the neutrons from the explosion caused the formation

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of a radioactive salt from the normal salt in the sea water. This radioactive salt then decayed, and in the process, emitted a great deal of gamma radiation. Thus, the neutron flux, which was generated at the instant of the explosion gave rise to a lingering type of radioactivity. One saving feature is that fact that neutrons do not have a range greater than one mile.

17. Beta particles are emitted at the instant of the explosion, but they are not a serious threat. The beta particle is a charged particle and will, therefore, have a short range in air. The most energetic beta particles from an atomic explosion have ranges of only about 10-11 yards in air Thus, while they are harmful, their range is so short that they need not be seriously considered, unless active beta particles are ingested.

18. Alpha particles also arise in the explosion. They are massive, compared with the beta particle, therefore their ranges may be measured in inches. If an alpha emitter becomes lodged in the body it can be a very serious hazard, but it is not a serious hazard as long as it is outside the body.

19. This concludes the list of harmful radiations which arise at the instant of the explosion. These include gamma radiation, visible light, ultra-violet and infra-red radiations, neutron flux, beta radiation and alpha radiation.

20. The radiation which arises at the instant of the explosion is not the only harmful radiation. There are types of radiations which persist after the explosion. This radiation arises from three sources. They are:

a. Unfissioned bomb material.
b. Fission products of the bomb material.
c. Radioactivity induced in the materials of the land or sea.

21. All of the material of a bomb does not undergo fission. This unfissioned material, either uranium-235 or plutonium is reduced to a powder and scattered by the explosion. This material is an alpha particle emitter. It is not much of a hazard, due to the short range of alpha particles in air, unless it is taken into the body through the lungs, mouth or open cuts. It then becomes a really dangerous hazard. This effect will be discussed in a later period.

22. A part of the bomb material undergoes fission. It has been pointed out that, in the fission process, the atoms of uranium or plutonium break up to form lighter atoms and that these newly formed atoms are radioactive. They decay by the emission of beta particles and gamma radiation. The beta particles are a lesser hazard than the gamma radiation since they, like the alpha particles, do not have a great range in air. The gamma radiation is very dangerous for considerable distances and, since the fission products will also be widely scattered by the explosion, may be dangerous over a large area after an explosion.

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23. The hazard due to induced radioactivity can be great in some types of explosions. This hazard is produced by the neutrons which are released at the instant of the explosion. These neutrons enter the nuclei of some atoms and cause a physical reaction which leaves a radioactive atom as a product. The induced radioactivity for the atomic explosion over land is variable depending on what type of soil exists. The Bikini test showed that for underwater bursts great amount of radioactivity are induced. This is due to the fact that the salt in the sea takes up neutrons to form a radioactive isotope of sodium. This radioactive sodium decays by emitting gamma and beta radiation and ends up as a stable isotope. Considerable gamma radiation, due to this reaction, was present after the Baker test at Bikini.

24. In the air burst of the atomic bomb, as in Japan, or the Able test at Bikini, the mass of fissionable material is dispersed by the explosion and a rapidly growing fireball is formed. This ball is white hot gaseous matter and has a temperature of well over a million degrees centigrade.

25. As the fireball radiates its immense heat, it becomes cool, then contracts, and the surrounding debris-laden air rushes in with hurricane velocity; at the same time the air above the fireball, being extremely hot, rises rapidly. These two forces combine to create the huge towering pillar of dark smoke which is characteristic of an atomic explosion. The cloud is laden with fission products and unfissioned bomb material. The latter material is due to the bomb is not one hundred percent efficient.

26. This radioactive material is carried high into the air, the column reaching more than 40,000 feet. In the case of an air burst, practically all radioactive material is carried up into the cloud.

27. Now this is very important since that radioactive material is very finely divided and is carried by the wind for long distances before it finally falls to the ground. Normally, after being carried many miles away from the bomb burst, the particles are so scattered as to be capable of little harm, but danger <u>can</u> exist up to quite a few miles.

28. A Radiological Defense Officer will be given adequate weather data by the Weather Officer. He can then calculate with fair accuracy just how far dangerous contamination will be carried and can plot the "fall-out" and "rain-out" areas which will be relatively safe, dangerous and extremely dangerous. The method by which this fall-out pattern is plotted is somewhat complicated and slow. Due to this the procedure is not included in this course.

29. In practice, if an atomic bomb falls on a city, port, or industrial concentration fifty miles or so from your base, you will be expected to note the presence of any radioactivity in your area, its intensity, degree of danger to personnel, and its extent.

30. With suitable instruments it is possible to detect the presence

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of radioactivity for many miles. It has been said that the atomic cloud from the Alamorgordo test was traced to Canada. Of course, after a relatively few miles, the particles were so dispersed that no damage was done, except in one case, that of a photographic manufacturing concern which used strawboard to pack a large quantity of film. The strawboard was made from plants on which radioactive particles had settled, many miles from the blast. As a result, several thousand dollars worth of film was ruined.

31. The underwater burst at Bikini on Baker Day had different results.

(INSTRUCTOR - REPRODUCE CHART 6-4 ON BLACKBOARD)

The bottom is coral, and water here was a little over 200 feet deep. The bomb had been lowered in a sealed caisson the night before, and was hanging somewhere below the ship. When everything was cleared the next morning, the bomb was detonated. Upon detonation, as was anticipated, an extremely great quantity of energy was emitted which formed a ball of incandescent gas. The water was simply thrust away and much of it vaporized. The pressure in the gas bubble was over a million pounds per square inch. The surface broke, and the water vapor went straight up. The "Prompt" radiation came out before the bubble broke and was absorbed in the mass of water. The shock wave of the explosion was bounced off the bottom and was reflected just in time to pick up much of the water that rushed in to fill the hole that had been made. The column of water rose rapidly. It was really not very dense, in spite of its ominous appearance in the film; it was largely foam with only a few massive chunks of solid water included in it. The water reached its peak, then fell around the rest of the ascending column, and upon reaching sea level it made a collar effect around the base of the column. This collar, called the base surge, moved outward at about 80 miles an hour, and grew rapidly in its vertical dimension. It reached a total height of over 300 feet and was over one quarter of a mile across on one side. From this base surge, and from the still overhanging cauliflower above, heavy rain fell on everything below. This rain was of cloudburst intensity and very heavily contaminated. Even the salt in the sea water had become radioactive, due to the neutron flux, and decayed with a half life of about 15 hours. Some fission products attached themselves to water droplets or dust particles and fell with them. The later progress of a base surge would depend on weather conditions. With normal wind velocities, a danger area of roughly 2 miles crosswind by 5 miles downwind may exist.

32. Had the Bikini bomb gone off in a harbor the contaminated rain could have enveloped buildings in the adjacent city, buildings with windows already broken by blast. Enduring contamination would have resulted.

33. After two years, some of the Bikini ships were still heavily contaminated. Some had to be sunk, others are being used for experiments in decontamination techniques, and others have been cleaned and returned to service.

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34. The following factors relative to an air burst and water burst should be stressed; in the air burst there is immense, so called prompt, radiation of gamma rays and neutrons. The fission products, themselves radioactive, and unfissioned bomb material, all are taken into the air and dispersed by normal weather processes. Only a relatively small amount of radioactive material settles to earth to cause significant contamination.

35. As for the time available for self protection; in an air burst, there is absolutely none. In the water burst, the base surge takes perhaps 10 seconds to form. The radiation, therefore, doesn't fall immediately. It might take 15 minutes to reach four miles downwind. Closer to the blast area, however, the danger comes very quickly.

36. Finally, in the water burst there is very little heat liberated. Most of it is absorbed by the water and therefore there is very little fire effect.

Are there any questions?

INSTRUCTORS' QUESTIONS:

1. How does the shock wave from an atomic explosion compare with that from an HE explosion?

2. What four types of radiation accompany the actual atomic explosion?

3. How far do the fission neutrons travel?

4. From what three sources does the residual alpha, beta and gamma radiation come?

5. What is one major hazard that is not present in an underwater ab atomic explosion?

6. What is meant by the term "fall-out"?

(NOTE TO INSTRUCTOR: Film "A Tale of Two Cities" will now be shown)

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CHART 6-1

COMPARISON OF HE & ATOMIC EXPLOSIONS

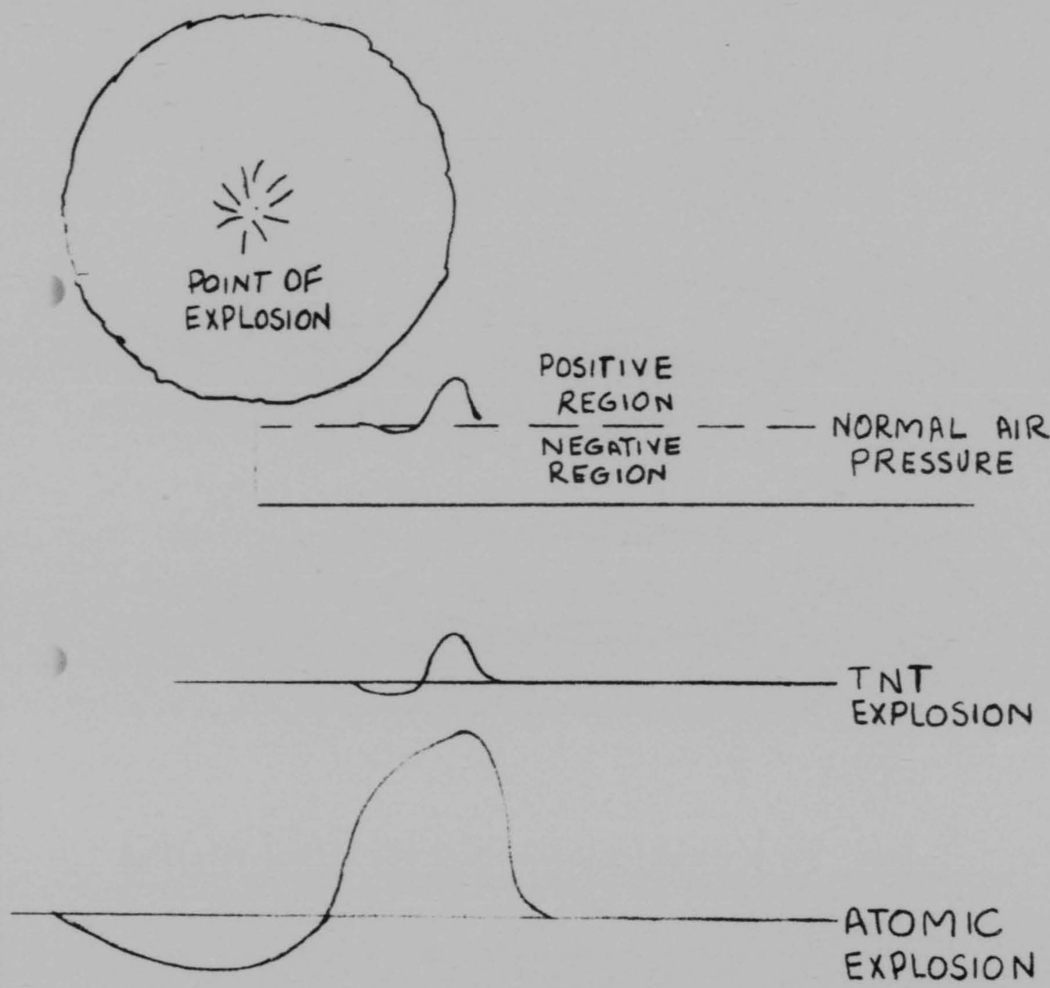

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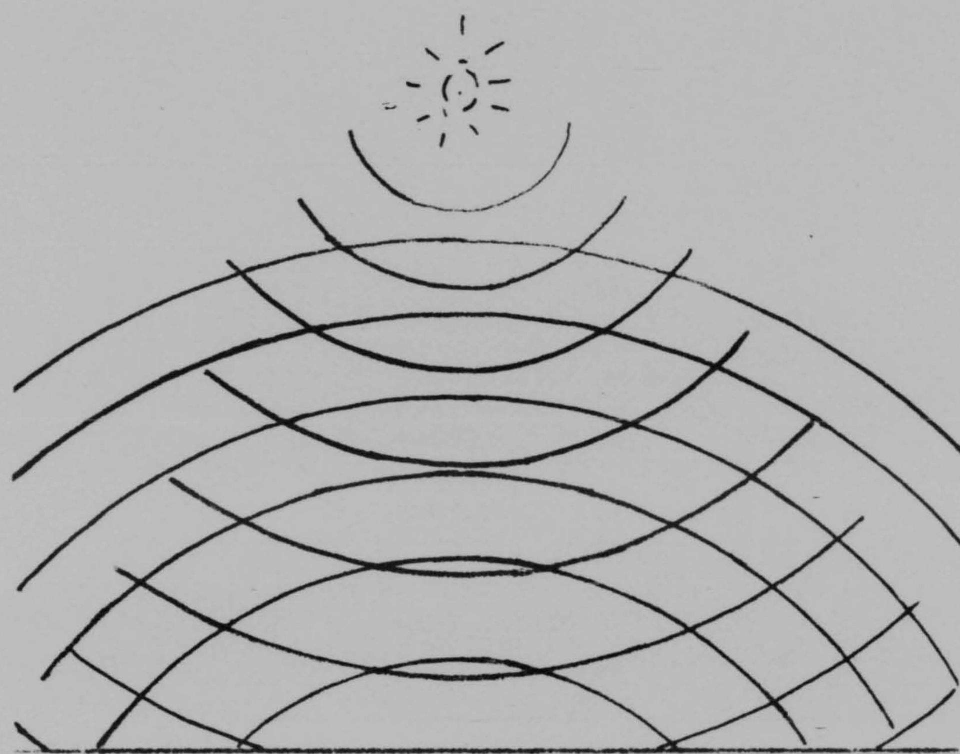
CHART 6-2



SHOCK WAVE REFLECTION

CHART 6-3

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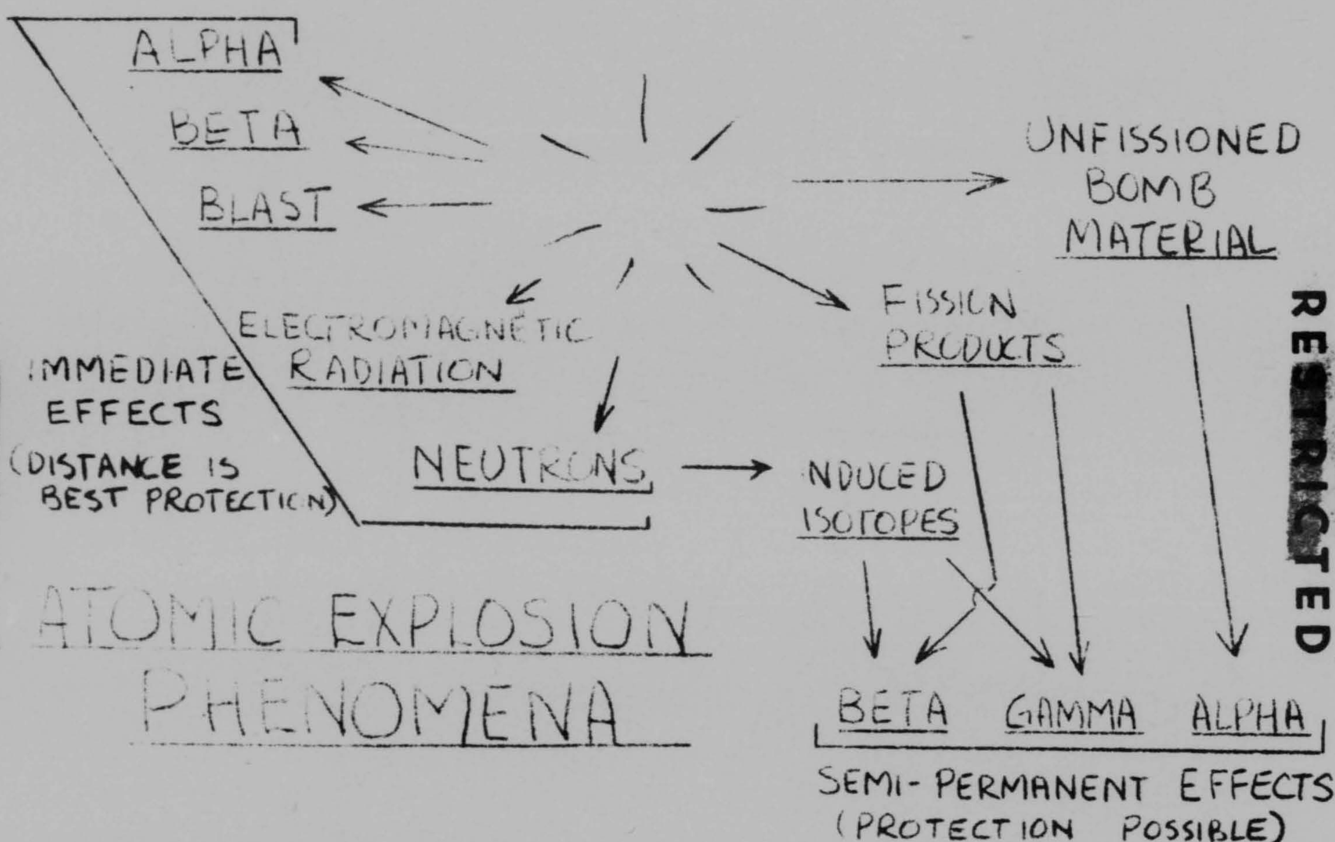

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CHART 6-4

BIKINI LAGOON

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TRAINING OUTLINE NO: 7

LECTURE: Effects of the Atom Bomb on the Human Body

TIME: One Hundred (100) Minutes.

PLACE: Classroom

INSTRUCTORS' REFERENCES: "The Effects of the Atomic Bombs on Health and Medical Services in Hiroshima and Nagasaki" USSBS, 1947; Chemical Corps School Mimeographs No. 21 and No. 202; Medical Aspects of Nuclear Energy", Armed Forces Special Weapons Project, National Military Establishment, 1949.

STUDENTS' REFERENCES: None.

TRAINING AIDS REQUIRED: Projector, Screen, Film "A Tale of Two Cities" (ANSM 74). Charts as Noted in text.

1. The two atomic bombs used in warfare up to the present time killed more than one hundred thousand people and injured a minimum of one hundred and fifty thousand. This talk on the medical aspects of the atomic bomb will tell us how these people died and will discuss the nature of the non-fatal casualties.

2. Japanese in authority have stated since the Hiroshima and Nagasaki bombings that, with proper organization, they could have saved ten percent of the fatal casualties. That means that twenty thousand men, women and children who might have been living today died - swiftly or slowly - because the defense was inadequate.

3. The estimated pre-raid population of Hiroshima was about two hundred and fifty five thousand, which is comparable to Providence, Rhode Island, or Dallas, Texas. The estimated deaths ranged from 70,000 to 80,000, with an additional 100,000 injured. In Nagasaki, a somewhat smaller town, with a normal population of about 195,000, there were 25,000 to 45,000 dead, and somewhere between 50,000 to 60,000 injured.

4. In both cities, approximately one quarter of the people were killed outright, and about half were injured, more or less seriously. The effects of the more efficient Nagasaki bomb were felt at a greater distance from Ground Zero, that is, the point on the ground directly underneath the air burst, than was the case at Hiroshima, but total damage was somewhat less in the Nagasaki explosion because the city was situated in a narrow river valley, and portions of the city were protected by hills and spurs projecting into that valley.

5. Before discussing the dead and wounded, let's give ourselves

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a reference point, that is, just how far from the explosion of the bomb does a man have a chance of being unharmed.

6. Averaging figures from both Japanese bombings with respect to distance from Ground Zero is interesting:

From Ground Zero to 1,000 feet approximately 95% killed
From 1,000 feet to 2,000 feet approximately 92% killed
From 2,000 feet to 3,000 feet approximately 86% killed
From 3,000 feet to 5,000 feet approximately 49% killed
After 10,000 feet there were many injured, but few or no fatal casualties.

7. These figures include all personnel of whom some were in shelters and many others protected by walls, buildings, or other shielding. For people outdoors, casualty figures were much higher.

8. This chart illustrates the emenations from an atomic explosion.

(INSTRUCTOR REPRODUCE CHART 7-1)

These include:

a. Blast from the explosion
b. Electro-magnetic radiation

Instantaneous:
(1) Infra-red
(2) Visible light
(3) Ultra-violet
(4) Gamma

c. Neutron Hail
d. Alpha
e. Beta
f. Beta and Gamma Radiation

Residual:
(1) From fission products
(2) From neutron induced isotopes

g. Alpha Radiation - From unfissioned bomb materials

9. At the detonation of the atomic bomb, a large fireball is produced which emanates all the above.

10. The infra-red radiations are heat waves of very high intensity. Many people were incinerated instantaneously at the moment of the explosion, and others suffered first, second, or third degree flash burns.

11. These flash burns were very productive of casualties. Temperatures, of course, were not accurrately measured, but the temperature possibly went as high as 2000°C up to over 1000 feet from Ground Zero. Clothing was instantaneously ignited up to 1500 feet away. There was scorching

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of telegraph poles 6000 to 9000 feet away. There were some odd effects from the infra-red waves; where they struck the unprotected skin, charring occurred and most victims died quickly. This effect was noted from 4000 feet to 5000 feet from Ground Zero. Second degree burns were inflicted up to 12,000 feet. Some persons reported feeling intense heat to the point of pain, up to 25,000 feet.

12. But there were some modifying factors such as clothing. Black clothing absorbed the infra-red rays, and severe burns resulted. White or light clothing, on the other hand, deflected the heat, and was definitely of good protective value. In many cases an odd piebald effect was created; as for instance where a man was wearing a striped or dotted garment, the darker portion of the pattern was burned into the skin beneath.

13. Thickness of clothing was a factor. The more layers a person wore, the more protection. Seams could be traced on the bodies in many cases, since they offered more protection, and superficial burning of the skin beneath was less severe. Burns were more serious also where the clothing was drawn tight against the skin.

14. Objects such as trees, fences, and blinds protected the skins of people who were behind them.

15. The visible light radiations have an intensity two or three times that of normal sunlight and affect the eyes. No permanent injury was caused in those persons far enough from Ground Zero to survive the blast, but there was a temporary blindness, lasting for minutes up to days, due to over-fatigue, or saturation, of the light-sensitive nerve surfact at the rear of the eyeball. There is some mystery as to why people did not have their eyes literally burned out or seared. The only reasons that can be ascribed for this are:

a. The overhanging bone or supradbital ridge over the eyes gives partial protection.

b. The blink reflex might have operated in the minute fraction of a second before the film of moisture on the eyeball was boiled away.

16. There are also the ultra-violet rays which are present in ordinary sunlight but are normally filtered out by the atmosphere. It was as though a small piece of the sun were instantaneously created just overhead. The ultra-violet rays may have caused first, second, or third degree flash burns, but this is not known, as such burns cannot be differentiated from those caused by heat.

17. Gamma radiation is highly penetrating and powerful. They cause interesting, but not attractive, biological effects which we will touch on later. Important to us is the fact that gamma radiation can penetrate and kill even through heavy concrete construction, or several inches of lead. The gamma radiation, together with the neutrons which we will

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discuss shortly, are responsible for the much publicized radiation sickness which killed many people who might have survived the atomic bombings otherwise. These people received an overdose of radiation sufficient to produce drastic changes in the body. In cases where exposure was of a lower order, effects might not be noticed until days or weeks later.

18. There is the phenomena of neutron-induced radioactivity that should be mentioned. The neutron flux or cloud of high-speed neutrons that are driven in every direction from the atomic explosion has the property of inducing radioactivity in other substances, notably metals.

19. Several interesting oddities occurred in the Japanese bombings. In one case, during an autopsy, a Geiger Counter showed a high order of intensity when brought near the head of a corpse. Further investigation showed that the subject's gold teeth had become radioactive. In another case, a man who must have been some distance from Ground Zero in order to survive at all, showed up days later with severe burns from a metal key and a cigarette lighter he was carrying in his pocket. They had become highly radioactive from the neutrons emanated in the explosion.

20. The direct effect of pressure on the human body was actually at a minimum since the body is rounded, streamlined, so to speak, and there is little direct impact effect. Of 92 cases examined in Nagasaki, only 2 showed ruptured eardrums. Of 106 cases at Hiroshima, only three were so afflicted. There were very few cases of intestines and other internal organs being blown out, and those were of people so close to Ground Zero that they would have died in any case.

21. It must be remembered that the indirect effects of pressure were a tremendous factor in causing personal injuries. We do not know how many people were killed by falling walls, broken glass flying, ceilings coming down, or loose bricks sailing through the air. All in all, it is estimated that the non-radiological hazards, that is, the heat and blast effects, were responsible for 75 percent of the casualties. To that extent, the atom bomb acted just as a giant explosive fire bomb, which indeed it is, to some degree.

22. Another aspect is the radiation hazard of the atomic explosion. An understanding of these hazards is essential to insure adequate protection and reduce casualties.

23. All radiation is to some degree destructive, since it produces ionization in the atoms composing the cells and tissues of the human body. Ionization is the stripping off of one or more electrons from an atom, and radiation causes this to take place in the body. When a few cells in a given organ or tissue are affected, no damage is done, but when a few million atoms in a given tissue are ionized, damage to that tissue results.

24. When elements that emit alpha particles are taken into the body, whether by mouth, or inhaled, or introduced through wounds, the ionization is caused directly by the alpha particles emitted from the radioactive

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atoms lodged in the body. Alpha particles cannot cause any trouble as long as substances emitting them are not taken into the body in some way. Beta particles have similarly poor penetrating properties and are essentially an internal hazard except for a caustic action on skin resulting from very high intensities.

25. On the other hand gamma radiation, X-rays and neutrons, all of which are emitted in immensely high intensities at the moment of the atomic explosion, (prompt radiation) can pass to the interior of the body, and cause wholesale ionization of atoms forming body cells, with consequent drastic tissue damage. These, therefore, constitute an external hazard.

26. The injury to tissues caused by radiation resembles that caused by nitrogen mustards.

27. As you can see, the ionization produced in the tissues is a direct measure of the damage done. There are some variable factors however:

a. Sensitivity of the particular tissue. The tissues which produce the red and white blood cells are most susceptible. Brain, and nervous tissue are least affected.

b. Ability of tissue to regenerate. Beyond a certain dose of radiation, all cells die, but with lesser amounts regeneration may take place, that is, the tissue may actually renew its destroyed portion. Muscle, brain, and eye tissue cannot regenerate. Liver, among others, can regenerate after almost complete destruction. In any case, however, repetition of radiation injury must be avoided.

c. Destruction and penetration. Radiation must reach vital tissues. Alpha particles have great energy but little penetration power in human skin. But, when alpha-emitting substances are ingested, the alpha particles given off cause grave damage within the tissues. Beta particles have considerably greater penetrating power and can produce greater penetrating power, and can produce skin irritations much like burns. It is when beta emitting substance are inhaled or ingested that damage is severe. The gamma rays penetrate deeply, as do the neutrons.

28. Now to consider radiation sickness in detail. It is an inescapable effect of overexposure to radioactivity. There are several definite effects.

a. On the Hair, Skin and Nails:

(1) The commonest effect of overexposure to radiation is loss of hair. In Hiroshima and Nagasaki, 75% of those within 1500 feet of Ground Zero who survived the blast, lost all the hair from the top of the head. Eyelashes,

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eyebrows, and beard are rarely lost. Very little effect on pubic or under-arm hair. Hair lost grows in again if the individual survives other effects.

(2) The fingertips may show damage to the point where fingerprints are affected, though this would be seen only under conditions of long continuing low intensity exposure. Similarly, the nails in such exposure may show brittleness and lonitudinal ridging.

b. On the Gastro-Intestinal Tract:

(1) This includes the mouth, esophagus, stomach, and intestines, in a word, the path that food takes through the body.

(2) This is often the first system to show damage effects of radiation. In milder over-exposures there may be nausea, vomiting, and perhaps diarrhea. Cramps may be noted. In heavier exposures, severe nausea, vomiting, and bloody diarrhea occur.

(3) Ulcerations of the muccus membrane of the mouth will be seen. Post mortem examination will show such ulcerations extending through the entire digestive system.

c. On the Reproductive Organs:

(1) All males examined showed lack of spermatogenesis, that is production of living sperm cells. It was more than a passing effect, for the sperm counts of survivors were low for months.

(2) Loss of sexual urge for extended periods was generally claimed, as was lack of potency. Malnutrition was the cause of this impotency and not the effects of radiation. It is agreed by all that temporary sterility can be caused by radiation but not imptence.

(3) Effects on the female occurred in various forms. Usually there was normal menstruation the following month, but after that menstruation was inhibited for varying periods.

(4) Many pregnant women had miscarriages, possibly a radiation effect but primarily due to fear, worry, and malnutrition as contributing factors.

(5) Vaginal ulcerations were noted; a usual effect on mucous membrane.

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(6) According to official statements, none of the expected mutations, that is, monstrosities or abnormal children have been born to survivors of the Japanese bombings. It is probabably too early to look for that sort of thing, but it is possible that the penetrating gamma rays may have brought about changes in the germ cells of a few survivors, and that these changes will eventually emerge. There is a long-range project in Japan for observing such effects, but so far, no abnormalities have been reported. It should be understood, however, that any such thing as future Japanese turning into two-headed people, and so forth, is improbable.

d. On the Blood Forming System:

(1) This consists of those organs which make or contribute to the making of blood. The red blood cells, the white blood cells, and the platelets are the most important cellular parts of the blood, and the developing cells of these are very sensitive to, and easily affected by radiation. Several definite effects follow:

(a) First, on the red blood cells. These are the cells which carry oxygen from the lungs to the tissues of the body, and carry carbon dioxide from the tissues to the lungs to be thrown off. When overexposed to radiation, the bone marrow which produces these red blood cells is damaged, and the result is anemia, of greater or lesser severity depending upon exposure.

(b) Next the white blood cells. These cells combat infection in the body by actually devouring invading bacteria, and "walling off" any points of entry of infection in the body. When the tissues that produce these white cells are damaged, the resistance of the body to stray infection is much reduced, and a person whose white blood cells are depleted falls an easy victim to disease. This condition is known as leukopenia.

(c) Then there are the platelets, which aid in the clotting of blood. Without them, or when their numbers are drastically reduced, the individual may hemorrhage from any small wound. Some Japanese had blood oozing from the unbroken skin due to platelet damage.

(2) Mortality figures indicate that destruction of these three types of cells is the most important single effect of radiation. With massive doses, all three

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elements are destroyed. With smaller doses, recovery may take place.

29. Now, a little more detailed discussion of the two types of radiation hazards. There are both external and internal hazards. These must be understood separately and in combination. External is defined as radiation from outside the body. Internal hazard refers to radioactive materials working from within the body after inhalation, ingestion, or penetration by other means.

a. External Hazards.

(1) Exposure to the atom bomb burst simulates overexposure to a giant X-ray machine. However, X-rays from a machine come normally from a point source, whereas with the bomb, the source is a large and expanding one. The difference is that radiation from a point source usually effects only one part of the body, whereas that from an extended source effects the entire volume of the body. Also, with the bomb, we have the deadly neutron flux, with a range extending over 800 yards.

(2) The accepted medico-legal tolerance dose that is set as a standard is .1 Roentgen units per day, that is, 100 milliroentgens. That is, we say that a man can safely take exposure to .1R per day indefinitely. Should he be exposed to, say, .2R in working with radioactive material, or on contaminated ground, that man should be kept away from radioactivity the day after. If he has exceeded his allowed .1R dose by .2, .3, or .4R, he should be kept out of contact with radioactivity for 2, 3, or 4 days as the case may be. That is, it is assumed that the body can throw off any damaging effect from exposure to .1R. For additional exposure a recovery time of one day per .1R must be allowed.

(3) Medically, as much as 2,000R can be used from a point source on a limited body area. It is claimed that as much as 14,000R has been used in treatment of brain cancer.

(4) The factors in external radiation having effect on extent of injury are:

(a) Size of Dose: In general, the greater the intensity of radiation, where the entire body is exposed, the greater is the absorption, and the more injury follows.
The accepted scale is as follows:

.1R per day. Completely safe. Our working tolerance.

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(Following doses are assumed one-time total over a 2-week period)

.1R to 25R. Little risk.

25R to 100R. Some injury possible. Probably not incapacitation.

100R to 300R. Possible serious injury. Some early incapacitation. Some deaths, possibly delayed.

300R to 600R. Serious injury or probable death. Early incapacitation.

400R is LD 50. (Lethal dose for 50% of exposed personnel)

It is quite possible that the military wartime tolerance will be raised from .1R upward at some future time.

(b) Size of body area irradiated. This we have discussed. The greater the area, the greater the tissue damage.

(c) Energy of radiation: The greater the energy the greater the damage.

(d) Duration of exposure: This is not as important in itself as one might think. In general, one large all at once will do more damage than several smaller ones, all other factors being equal.

(e) Individual variations: Depending upon constitution, state of health, and other variables; some men die at 200R/day, others are known to have survived 500.

b. Internal Hazards.

(1) These hazards are well known from the radium industry. Radium coupounds, and many radioactive materials have a tendency to deposit in the bones, usually in the high-calcium portions, at which places the emission of alpha, beta, and gamma radiation works on the production of blood cells by the marrow in the bones. It results in a slow and rather unpleasant death. Some of you may may recall the case a few years ago where a group of women who had been employed as radium watch dial painters, slowly absorbed minute amounts of radium by pointing their brushes with their lips. They accumulated a fatal dose of radioactive salts, but it took them a few years to die.

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(2) The hazard, of course, is from the fall-out after an air burst or the contamination following an underwater burst. Quantities of radioactive bomb material and raioactive fission products are carried downwind, and deposited on the earth often miles from the point of explosion. Precautions must be taken against inhaling any of this material, taking it in through the mouth, or getting it into open cuts or wounds. For that reason, under certain conditions such as dust, you may wear a gas mask in such a contaminated area, and you never eat, drink, or smoke until you are in an uncontaminated area.

(3) Looking at the over-all picture of casualties from radiation sickness in Japan, several general groups seem to be distinguished:

(a) Death occurring within first two weeks:

1. There were those who died immediately. There was a shock-like state, with weakness and general prostration. Such deaths were probably due to simple mass tissue destruction.

2. Those who lingered a few days or a week or more, didn't have time to develop all typical symptoms of radiation sickness. Patients showed nausea, vomiting, and possibly bloody diarrhea, but no loss of hair. Temperature rose and fell on a mounting curve, until death ensued.

(b) Death after six weeks. These cases were largely of people who survived above manifestations, and died of secondary infections, because of depletion of white blood cells and a variety of contributing factors.

(c) There were practically no deaths after six to eight weeks. General health appeared good in those who recovered, though our teams reached bombed cities too late for accurate assessment of all data. The possible incident skin cancer in the future is still in doubt.

(d) It is estimated that about 10% of fatal casualties could have been saved with adequate medical care. A possible course of treatment for future similar casualties is being developed. Extreme sterile techniques are indicated because of low white blood cell count of victims. Careful nursing is necessary, with special attention to skin. Generous transfusions of whole blood are indicated, as is use of certain vitamins.

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[redacted]

30. Summing up, the best avaiable statistics for both Hiroshima and Nagasaki indicate that blast and secondary injuries were responsible for between 50 and 60 percent of the casualties. Flash burns accounted for 20 to 30 percent more, and radiation sickness for about 15 percent. Those figures are necessarily approximations. We must suppose, also, that a goodly number of casualties were victims of blast, burns, and radiation, and even if the effects of blast and fire had been lacking, the casualties from prompt radiation would have been nearly as great.

31. This chart gives an over-all picture of death and injuries.

(INSTRUCTOR - REPRODUCE CHART 7-2)

It is intended to give you a general idea of what might occur and the order of magnitude for range of casualty effect that might reasonably be assumed.

32. To review briefly: At the moment of the atomic bomb burst, there are blast, heat, and prompt radiation. This prompt radiation is all considered as external hazard. Then, as the atomic cloud drifts downwind, and the unfissioned bomb material and fission products fall out, there is an invisible layer of radioactive material on the ground. This emits beta and gamma radiation which is an external hazard; it is also an internal hazard in that the very finely divided material may be breathed in, find entrance through wounds, or be swallowed, in which case the alpha and beta radiation given off does grave damage within the body.

33. Radioactive dusts, which can be used as a weapon, present the same picture as this residual contamination after an explosion, except that an enemy using them deliberately can pick a material that will keep an area uninhabitable for pretty much as long as he chooses - days, weeks, months, or years.

Are there any questions?

INSTRUCTOR'S QUESTIONS:

1. What effect does infra-red and ultra violet radiation have on the human body?

2. What effect does gamma radiation have on the human body?

3. What effect do alpha particles have on the human body when outside the body? When inside the body?

4. What effect do beta particles have on the human body?

5. What is the present tolerance dose of radiation?

6. What is meant by internal and external hazards?

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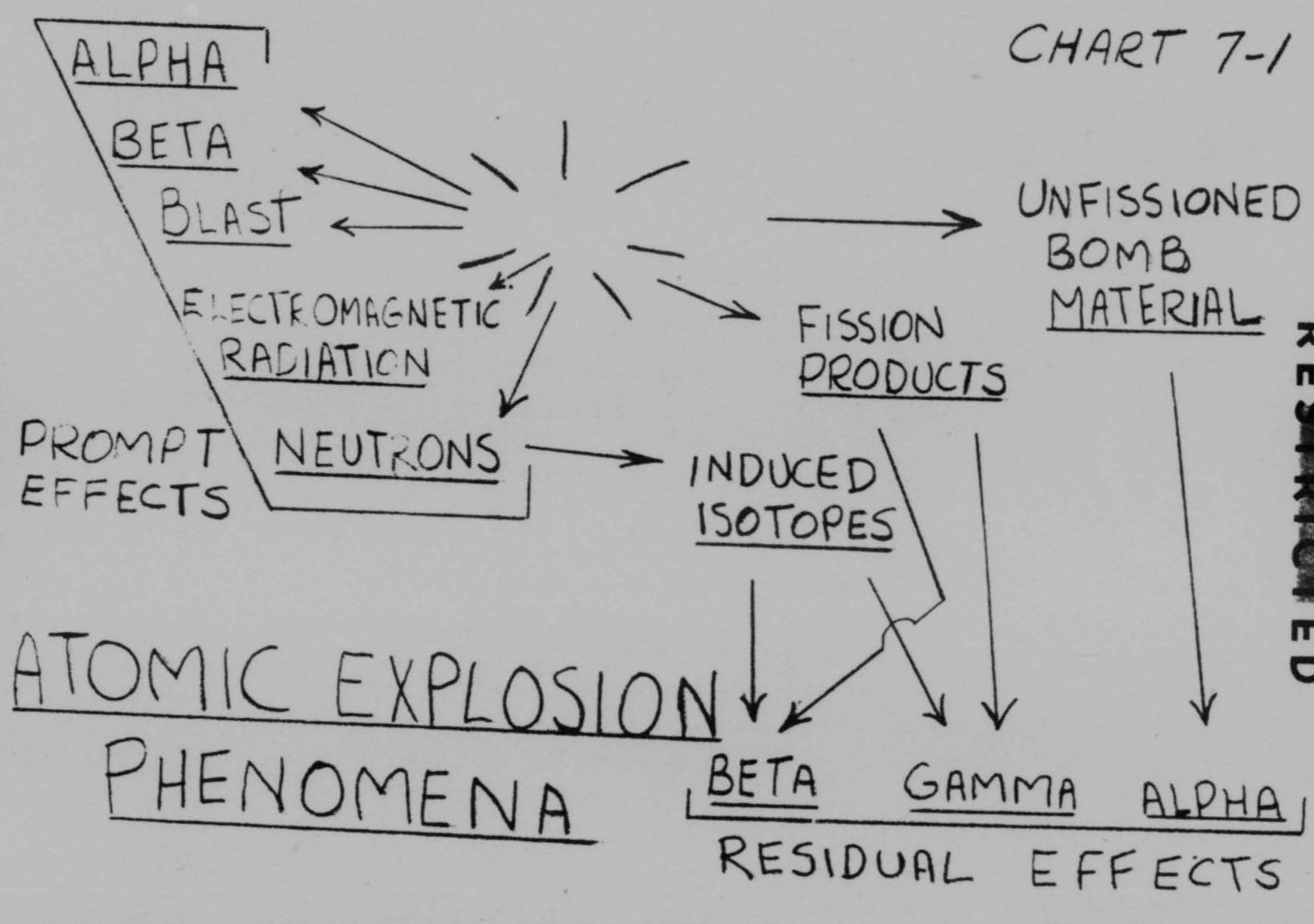

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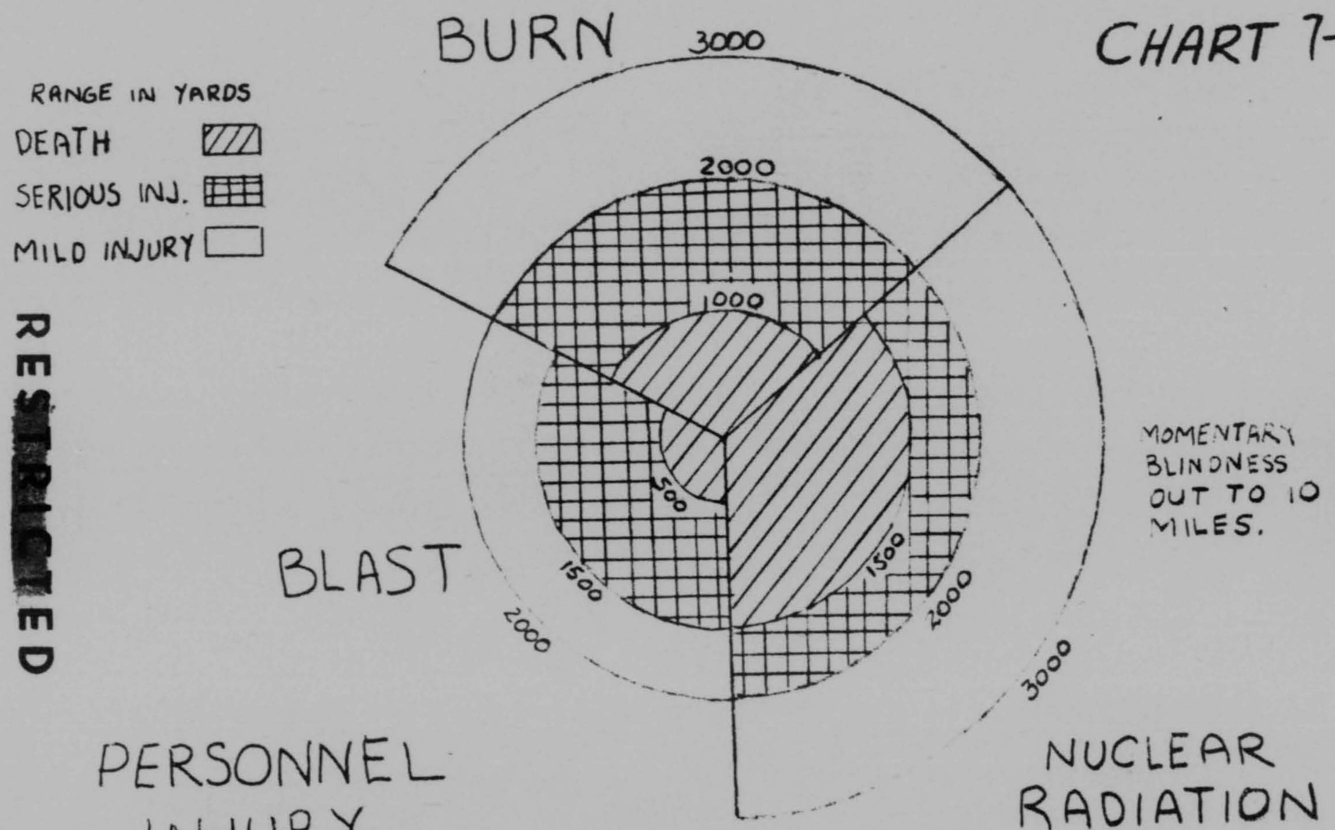
CHART 7-2



PERSONNEL
INJURY
CHART

[redacted]

TRAINING OUTLINE NO: 8

LECTURE: Review of Basic Arithmetic.

TIME: Fifty (50) minutes.

PLACE: Classroom.

INSTRUCTORS' REFERENCES: Any available arithmetic text.

STUDENTS' REFERENCES: Any available arithmetic text.

TRAINING AIDS REQUIRED: None.

Certain problems and procedures which arise in radiological defense work require mathematical calculations to arrive at an intelligent answer. These calculations are made more laborious by the fact that the large and small numbers, involving decimals, are involved. Experience has proven that the major difficulties encountered in this phase are due, not to complicated methods being involved but to errors in simple arithmetic. To brush up on this arithmetic a short review of the subject will be presented. In effect we are going to jump back to grammar school for an hour and study addition, subtraction, multiplication and division. Following this hour each student will be given a set of short problems to work similar to those covered in the review.

(INSTRUCTOR - REPRODUCE ALL EXAMPLES GIVEN IN THIS LECTURE)

a. Addition: Addition is the operation of finding the sum of two or more numbers. The simple addition of

$$2 + 2 = 4$$

presents no difficulties. Even the addition of

$$9 + 6 = 15$$

is very simple although the answer is a number consisting of two figures. The addition of larger numbers such as

$$29 + 76 = 105$$

requires closer attention however, since it is generally necessary to place them in a column, so

$$\begin{array}{cc} 2 & 9 \\ \underline{7} & \underline{6} \end{array}$$

add the right hand column first

[redacted]

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[redacted]

```
 9
 6
15
```

record the figure 5, carry the figure 1 to the column next left and add it in there, thus

```
 2
 7
+1
10
```

and giving us a final answer of

```
(+1)
  2 9
  7 6
1 0 5
```

Errors are likely to creep in when we tackle a problem like the following

```
 278
   9
9593
  28
9908
```

since there is a tendency to forget the number carried to the column next left or to line the columns up incorrectly. The possibility of error increases when quantities like the following are dealt with

```
 278.13
   9.017
9593.003
  28.0
9908.150
```

since decimal quantities seem to be a stumbling block.

A decimal is a fraction whose denominator is 10, 100, 1,000 or any other power of 10. The denominator is not written, but is indicated by the position of the decimal point. For example

2.5 = 2 + 5/10
2.53 = 2 + 53/100
2.536 = 2 + 536/1000

Decimals should not be confused with common fractions such as 1/2, 1/4, 21/45 which have a denominator other than 10. Common fractions may be converted to decimals, however, through a process of division which will

[redacted]

be covered later.

With reference to addition of decimals the essential point is to carry the figures in columns to the RIGHT of the decimal point. Example

3.	0	0	1	2
8.	1	9		
5.	0	4	1	
2.	0	3	0	8
18.	2	6	3	0

The value of a decimal is not changed by adding zeros to the right of the figures. Thus

1.2 is the same as 1.20000

Therefore, for convenience, it would be permissable to write the above sums as

3.	0	0	1	2
8.	1	9	0	0
5.	0	4	1	0
2.	0	3	0	8
18.	2	6	3	0

in order that the proper arrangement of columns is made simpler.

The value of a decimal is changed by adding zeros between the decimal point and the left significant figure. Thus

0.2 is not the same as .02

and

$$\begin{array}{r} 0.2 \\ +\ 0.02 \\ \hline =\ 0.22 \end{array}$$

The cardinal rule to remember in addition is that whole numbers should be arranged with the columns in order from right to left while decimals are added with the columns in order from left to right using the decimal point as a guide.

b. Subtraction: Subtraction is the operation of finding the difference between two numbers. As such it is an exact reversal of the process of addition. The most frequent source of error lies in the following type of problem.

$$\begin{array}{r} 93478 \\ -24589 \\ \hline 68889 \end{array}$$

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[redacted]

where it is necessary to "borrow" one unit from the column next left, so

```
         9 3 4 7 8
         2 4 5 8 9

first    9 3 4 6 (18)
         2 4 5 8   9
                   9

second   9 3 3 (16) (18)
         2 4 5   8    9
                 8    9

third    9 2 (13) (16) (18)
         2 4   5    8    9
               8    8    9

fourth   8 (12) (13) (16) (18)
         2   4    5    8    9
         6   8    8    8    9
```

and, involved in the actual subtraction, we forget "what" was "borrowed" from "where".

The best method of checking subtraction is to re-add the answer obtained with the number subtracted and see if we obtain the original quantity, thus

```
          ->  9 3 4 7 8    (subtraction)
         /   -2 4 5 8 9
        /     6 8 8 8 9
Same  <
        \     6 8 8 8 9    (check)
         \   +2 4 5 8 9
          ->  9 3 4 7 8
```

therefore, the answer, 68889, is correct. Again care should be exercised to line up the columns as outlined in the section on addition.

c. <u>Multiplication</u>: Multiplication is a process of wholesale addition. It is assumed that each student can recall the multiplication table up to the number 10. On this basis the straight-forward multiplication of two whole numbers is quite simple, as shown by the example

```
 283
 x47
```

first multiply through by 7

[redacted]

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[redacted]

```
 2   8     3
           7
14  56 (2)1
+5  +2
19(5)8            or 1981
```

then multiply through by 4

```
 2   8     3
           4
 8   32 (1)2
+3  +1
11 (3)3           or 1132
```

adding the two results with the second number set one column to the left

```
 1981
1132
13301
```

gives our answer.

Errors are more likely to appear in the following type of problem.

```
 258
x103
```

where one is undecided about how to handle the term 0. Multiplication by 0 yields zero and, while mathematicians would cry a protest, one convenient way to keep the columns in proper order is as follows:

```
  258
 x103
  774
 000
258
26574
```

The important rule is to move the result of each multiplication one column to the left of the preceeding multiplication before adding.

The final point to be covered on multiplication concerns multiplication of decimals. Several cases must be covered here. The first case is illustrated by the problem

```
 1.3
x2.6
```

Now neglecting the question of decimals for a moment, we carry out the actual multiplication and obtain

[redacted]

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[redacted]

```
 1.3
x2.6
----
  78
 26
----
 338
```

Obviously 338 is not the actual answer since we multiplied a number of less than 2 by a number less than 3. 2 x 3 is 6 and so our answer must be less than 6. The answer is actually 3.38, a figure obtained by counting the total number of significant figures to the right of the decimal points in the two numbers multiplied, thus

```
 1.3 (1)
x2.6 (2)
```

giving two figures. Now we go to the answer obtained, count off two places from right to left

```
3    3    8
  (2)  (1)
```

and place our decimal

3.38

Another typical problem would be

```
 3.24
 x1.7
-----
 2268
 324
-----
5.508
```

The second case involving decimals looks like this

```
 3.24
 x.03
-----
  972
 000
-----
.0972
```

and is handled in exactly the same manner.

A final case of decimals often shows up as

```
  .038
  x.21
------
   038
  076
------
.00798
```


[redacted]

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[redacted]

and turns out as indicated. A word of advice is in order here. The last illustrated problem came out with five decimal places to be marked off in the answer but with only the three significant numbers. This is handled by placing as many zeros to the LEFT as necessary - in this case, two - and then placing our decimal point so

.00798

It might be well to point out what is meant by significant figures. If we take the number 2 as an example it is correctly written as

2.
or
2
or
00002.
or
2.00000000000

but the zeros are not significant. If we write 2 without the decimal immediately following and add a string of zeros, so

200000000

then the zeros are significant and the number is not 2 but 200 million. Specifically zeros added to the left of whole numbers are not significant and zeros added to the right of decimals are not significant.

Example 00002. and 2.13000000

Zeros added between the decimal point and the numbers of a decimal are significant.

Example .0013
.00 (00) 13 Significant
.0013 (00) Not significant

Zeros which are not significant should be dropped.

d. Division: Division is the process of finding how many times one number is contained in another. Division takes two forms; short division and long division.

Short division is the simple case where one figure is divided into any number. An example is

2 / 44
22

and another

2 / 4572

[redacted]

[redacted]

which is handled as

```
2/ 4      2/ 5           2/(1)7          2/ (1) 2
   2        2(plus 1)       8(plus 1)           6
```

and our answer is 2286.

To handle decimals in short division, it is only necessary to inspect the numbers involved and the answer is apparent

Example 6/343.8

```
6/ 34     6/ (4)3     6/ (1)8
    5           7           3
```

or 573 which is obviously 57.3. Since the answer when multiplied by 6 must yield 343.8.

Long Division is usually the stumbling block for most persons so it will be considered in some detail by means of numerical problems.

Example 1. Exactly divisible.

```
18/23526
```

Step 1. Estimate number of times 18 can be divided into 2. Answer is zero.

Step 2. Estimate number of times 18 can be divided into 23. Answer is 1. Mark up, Multiply 18 by 1, mark result down under 23 and subtract.

```
     1
18/ 23 ---
    18
     5
```

Step 3. Mark down next number to right

```
     1
18/ 23526
    18
    55
```

Step 4. Estimate number of times 18 can be divided into 55. Answer is 3. Mark up 3, Multiply 18 by 3, mark down result under 55 and subtract.

```
     13
18/ 235 - -
    18
     55
     54
      1
```


[redacted]

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Step 5. Mark down next number to right.

```
       13
  18/ 23526
      18
       55
       54
        12
```

Step 6. Estimate number of times 18 can be divided into 12. Answer is zero so mark up zero and then mark down final number to the right.

```
       130
  18/ 23526
      18
       55
       54
        126
```

Step 7. Estimate number of times 18 can be divided into 126. Answer is 7. Mark up 7, multiply 18 by 7, mark down result under 126 and subtract.

```
      1307
  18/23526
     18
      55
      54
       126
       126
         0
```

Answer is 1307.
To check multiply 1307 x 18 and obtain 23526, the original number.

Example 2. Divisible with a remainder

```
      3 8 9 8
  12/46 7 6 2
     36
     107
      96
      116
      106
       102
        96
         6
```

Answer 3898 6/12
= 3898 1/2
or 3898.5

The method whereby 1/2 (a common fraction) was changed to 0.5 (a decimal) will be used as the next example.

[redacted]

Example 3. Division with decimal answer.

```
2/1
```

Step 1. Place decimal after 1 and add a zero. Now ignore decimal until later

```
2/1.0
```

Step 2. Estimate number of times 1 can be divided by 2. Answer is 0. Mark up 0 and estimate number of times 10 can be divided by 2. Answer is 5. Mark up 5, multiply 2 by 5, mark down result under 10 and subtract.

```
   0 5
 2/1.0
   1 0
     0
```

Answer is 05 but this is not the final answer since the decimal point must be located. To do this we count the number of places to the left of the decimal in the number divided, in this case one and then count off this same number from the right in our answer giving us

0.5 or simply .5

the final answer.

Example 4. Division with decimals.

```
          093.50          300/304
 3.04/ 284.2700
       2736
        1067
         912
         1550
         1520
          300
```

One additional point about determining decimal point location in the answer. In making the initial trial for a dividing number the trial should be made of the same amount of numbers as are in the dividing number.

Example 18.2/ 32715.003

Try dividing 182 into 327. If it will go (in this case, yes) put down the number (in this case, 1) and continue. If it will not go, as in the following case

18.2/ 108715.003

mark up a zero and then try dividing 182 into 1087.

Are there any questions?

[redacted]

[redacted]

TRAINING OUTLINE NO:	9
CLASS EXERCISE:	Practice on Assigned Mathematical Problems.
TIME:	Fifty (50) minutes.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	None.
STUDENTS' REFERENCES:	None. Students may use notes.
TRAINING AIDS REQUIRED:	Mimeographed problems, pencils, scratch paper.

1. Instructor will have the attached set of problems reproduced and will have each student work out the problems as a classroom exercise.

2. Problems should require about 35 minutes to complete, following which the papers should be collected and questions answered. Papers should be graded and returned to students.

3. Additional paper should be distributed for student to solve problems involving multiplication and division.

4. Answers from division problems involving decimals should be worked out to the second figure, other than zeros, after the decimal point.

[redacted]

PROBLEMS

Perform indicated operations:

ADDITION. (Approximately 5 minutes)

1.	2.	3.
19	112	527,101
28	150	198,620
36	856	412,680
40	665	210,863
51	1291	768,510
98	64	169,087
107	671	307,627

4.	5.
10,471,998	7.0885
250,469	9.1548
984,323	4.8118
14,110,652	9.0519
3,081,467	4.0383
6,843,147	38.4197

SUBTRACTION. (Approximately 3 minutes)

6.	7.	8.
296	73.4	6.29
107	31.9	4.03

9.	10.	11.
93.203	37,451	1607.5362
30.866	35,689	1098.7496

MULTIPLICATION.

12.	13.	14.
931	8638	3.04
856	6387	2.15

15.	16.	17.
26.382	.0708	23.007
.003	.0091	1.3

18.	19.	20.
.009	83.967	1.000
.009	39.281	2.0

[redacted]

DIVISION.

21. $\frac{238}{14}$ 22. $\frac{1785}{31}$ 23. $\frac{27.6}{0.31}$

24. $\frac{0.03715}{18.7}$

COMBINED OPERATIONS.

25. $\frac{18.3 \times 0.03}{1.7}$ 26. $\frac{8.3 \times 281}{284}$

[redacted]

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[redacted]

TRAINING OUTLINE NO:	10
LECTURE:	Logarithms and Calculation of Multiple Half -life Decay.
TIME:	Fifty (50) minutes.
PLACE:	Classroom
INSTRUCTORS' REFERENCES:	Any available Algebra text.
STUDENTS' REFERENCES:	Any available Algebra text - Section dealing with logarithms.
TRAINING AIDS REQUIRED:	Mimeographed copies of Chart 10-3, pencils, scratch pads.

1. The existence of widespread radioactive contamination in the vicinity of an atomic explosion has been previously discussed. The fact that this contamination consists of a mixture of fission products, unfissioned bomb material and neutron induced isotopes has also been discussed. The fact that dozens of different isotopes decay simultaneously but each with a different half-like may be recalled from our discussion of radioactivity. Finally we now know that any person entering an area where he receives a dose of radiation greater than 100 milliroentgens per day may suffer harmful physiological effects. All of these points contribute to a problem encountered in radiological defense work that may be stated as follows:

a. "How rapidly will radioactive contamination decay to a point where personnel may safely reenter the effected areas for extended periods of time?"

b. A specific general answer cannot be given since no two atomic explosions are ever exactly alike; there is a general mathematical relationship, however, which is of value.

2. Assume that the data below have been taken at a point in the contaminated areas after two separate atomic explosions. This might well be the case if one explosion were underwater and the other near the surface of a land mass.

[redacted]

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EXPLOSION NO. 1

Time after Explosion	Measured Intensity
1 day	100,000 mr/day
2 days	35,300 mr/day
4 days	12,500 mr/day
10 days	3,170 mr/day
15 days	1,730 mr/day
20 days	1,130 mr/day

EXPLOSION NO. 2

Time after Explosion	Measured Intensity
1 day	400,000 mr/day
2 days	100,000 mr/day
4 days	25,000 mr/day
10 days	4,000 mr/day
20 days	1,000 mr/day

3. A glance at these data shows that after Explosion No. 2 the residual radiation, due to radioactive contamination, was more intense initially but that it decayed more rapidly than was the case for Explosion No. 1. When plotted as curves however we see that each curve has the same shape.

(INSTRUCTOR - REPRODUCE CHART 10-1)

Without going into involved mathematics it may be stated simply that because these curves have the same general shape, and because a general mathematical relationship holds for all such curves, that a general mathematical relationship exists for decay of radioactive contamination. This general mathematical relationship is

$$It^n = K$$

where:

I is the radiation intensity at time t

t is the time since the explosion

n and K are constants as determined by each explosion. These are different for each explosion.

4. This equation is quite simple but to use it for calculations requires a slight knowledge of exponents and logarithms.

a. Starting with the procedure for squaring and cubing numbers, if we want to square 2, the expression is written as

$$2^2 = 4$$

and if we wish to cube 2, the expression is written as

$$2^3 = 8$$

[redacted]

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[redacted]

In other words, when we square a number, a, we raise the number a to the second power and when we cube a number, a, we raise the number a to the third power. The general form for raising any number, a, to any power x, is given by the term

$$a^x$$

which means merely that a is to be multiplied by itself x times, and this expression is mathematically the same as the term

$$t^n$$

in our decay equation. Now when the power, to which we wish to raise a number is an exact figure the process is quite simple - we simply multiply the number by itself as many times as the power indicates - as for example

$$2^6 = 2 \times 2 \times 2 \times 2 \times 2 \times 2$$
$$= 64$$

or

$$3^4 = 3 \times 3 \times 3 \times 3$$
$$= 81$$

but the case of

$$2^{2.61}$$

is something more complicated. Without mathematical derivation, let us say that this expression must be written as

$$2.61 \log 2$$

to get our answer. And that brings us to the matter of logarithms.

b. For our purposes, logarithms will be considered as auxiliary numbers: one auxiliary number existing for each real number and each auxiliary number being the sum of a number and a decimal fraction.

$$\text{Log N} = (\text{a number}) + (\text{a decimal fraction})$$
$$= \text{characteristic} + \text{mantissa}$$

The characteristic indicates the order of magnitude of the numbers involved. These characteristics are as follows for positive numbers:

No.	Characteristic
1 - 9	0
10 - 99	1
100 - 999	2
1000 - 9999	3
10,000 - 99,999	4

We will not consider the case of negative numbers in this course.

[redacted]

[redacted]

c. Mantissas are determined by use of Chart 10-2

(INSTRUCTOR - PASS OUT CHART 10-2)

To find the mantissa of a number, say 283, locate the first two figures of the number, 28, in the left hand column; then go horizontally right until the third figure of the number, 3, is lined up vertically. The answer, 451, is read at the intersection.

Examples of the logarithms of several numbers are:

			Characteristic		Mantissa
log 300	= 2.477	=	2	+	.477
log 23	= 1.361	=	1	+	.361
log 8745	= 3.941	=	3	+	.941
log 100	= 2.000	=	2	+	.000

Conversely, when dealing with these auxiliary numbers, it is necessary to transpose them back to actual numbers. Thus if we have the logarithm

1.426

it is necessary to obtain the number which it represents. To obtain the number we take the mantissa, 426, and look it up in the table, obtaining 267 - which is our number. The characteristic of 1 indicates that the number is of magnitude between 10 and 99, which immediately shows that the number is

26.7

This number we call the anti-log.

Now let us work out a problem wherein we make use of these logarithms. Reference is made to the original example of

$2^{2.61}$ or (a^x)

which was rewritten as

x log a
or
2.61 log 2
now log 2 = 0.301
and (2.61) (0.301) = 0.301

```
  0.301
   2.61
  -----
   0301
  1806
 0602
 ------
0.78561
```

or 0.785

which when converted back to the actual number - or as we say "take the

[redacted]

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[redacted]

antilog" - gives

6.1

as the actual number or antilog and this is the method with which we calculate our term

$$t^n$$

in the decay equation.

With these new tools at our disposal, the multiple decay equation

$$It^n = K$$

becomes quite simple to handle. To facilitate our work a form worksheet

(CHART 10-3)

will be used. By carefully performing, in numerical order, the indicated steps no difficulties should be encountered.

5. To use this equation the following steps are performed:

(INSTRUCTOR - WORK ILLUSTRATIVE PROBLEM USING NO. 1 SET OF DATA)

a. As soon as possible after the explosion, obtain a reading with a survey instrument. Record the intensity in R/Day and the time since zero hours in days. Example, if it is 36 hours since zero hour, record the time as 1.5 days.

b. At a later time when there has been an appreciable reduction in intensity (minimum reduction of approximately 5 R/Day) take a second reading, record intensity and time in days SINCE ZERO HOUR.

c. Carry out calculations on worksheet down to Item 14.

d. Now the decay equation may be used to answer the question, "when will the contamination decay to a certain safe value?" We take the value that we want to know (normally 0.1 R/Day) and enter it as Item 14.

e. Calculations are carried out and Item 18 gives the time in days since Zero Hour when the intensity desired will be reached.

(INSTRUCTOR - When this has been completed, the students should be required to work out a problem utilizing data from Explosion No. 2.)

[redacted]

CHART 10-1

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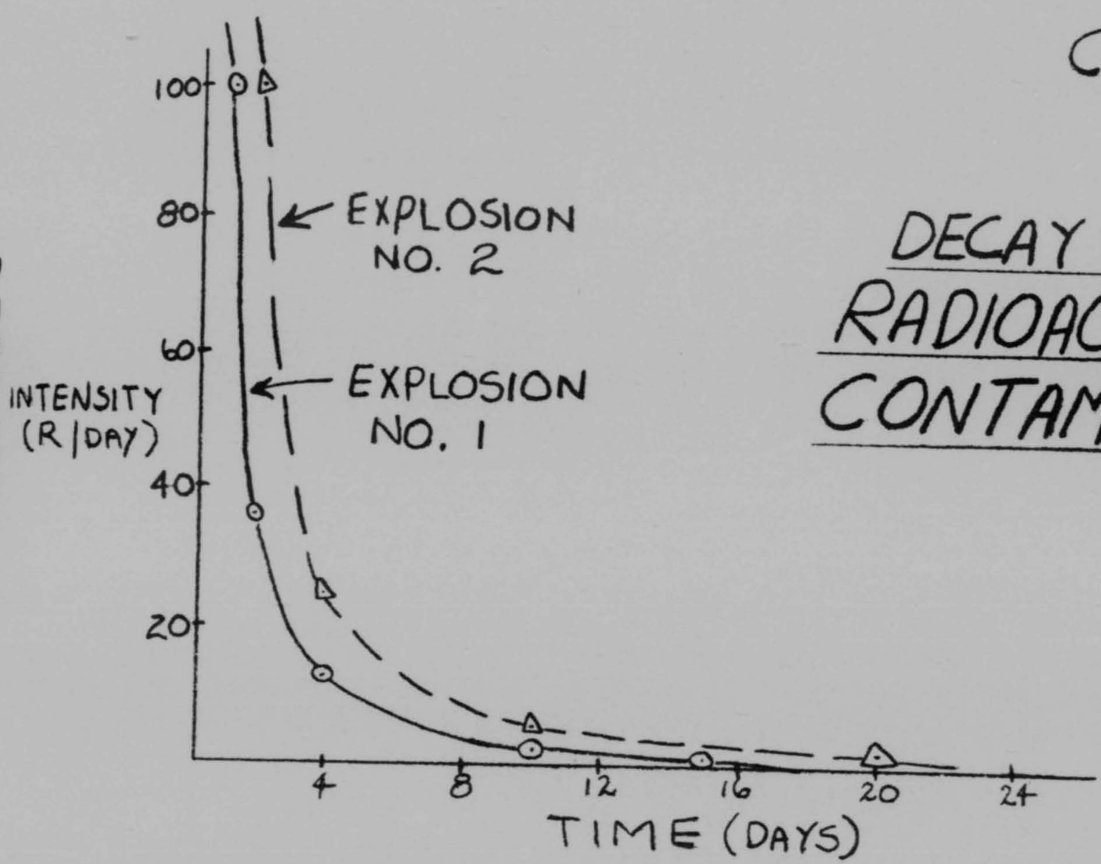

DECAY OF RADIOACTIVE CONTAMINATION

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CHART 10-2

LOGARITHM TABLE

N	0	1	2	3	4	5	6	7	8	9	N	0	1	2	3	4	5	6	7	8	9
10	000	004	008	012	017	021	025	029	033	037	55	740	741	741	742	743	744	745	745	746	747
11	041	045	049	053	056	060	064	068	071	075	56	748	749	749	750	751	752	752	753	754	755
12	079	082	086	089	093	096	100	103	107	110	57	755	756	757	758	758	759	760	761	761	762
13	113	117	120	123	127	130	133	136	139	143	58	763	764	764	765	766	767	767	768	769	770
14	146	149	152	155	158	161	164	167	170	173	59	770	771	772	773	773	774	775	776	776	777
15	176	179	181	184	187	190	193	195	198	201	60	778	778	779	780	781	781	782	783	783	784
16	204	206	209	212	214	217	220	222	225	227	61	785	786	786	787	788	788	789	790	791	791
17	230	233	235	238	240	243	245	248	250	252	62	792	793	793	794	795	795	796	797	798	798
18	255	257	260	262	264	267	269	271	274	276	63	799	800	800	801	802	802	803	804	804	805
19	278	281	283	285	287	290	292	294	296	298	64	806	806	807	808	808	809	810	810	811	812
20	301	303	305	307	309	311	313	316	318	320	65	812	813	814	814	815	816	816	817	818	818
21	322	324	326	328	330	332	334	336	338	340	66	819	820	820	821	822	822	823	824	824	825
22	342	344	346	348	350	352	354	356	357	359	67	826	826	827	828	828	829	829	830	831	831
23	361	363	365	367	369	371	372	374	376	378	68	832	833	833	834	835	836	836	837	837	838
24	380	382	383	385	387	389	390	392	394	396	69	838	839	840	840	841	842	842	843	843	844
25	397	399	401	403	404	406	408	409	411	413	70	845	845	846	847	847	848	848	849	850	850
26	415	416	418	420	421	423	424	426	428	429	71	851	851	852	853	853	854	854	855	856	856
27	431	433	434	436	437	439	440	442	444	445	72	857	857	858	859	859	860	860	861	862	862
28	447	448	450	451	453	454	456	457	459	460	73	863	863	864	865	865	866	866	867	868	868
29	462	463	465	466	468	469	471	472	474	475	74	869	869	870	871	871	872	872	873	873	874
30	477	478	480	481	482	484	485	487	488	490	75	875	875	676	876	877	877	878	879	879	880
31	491	492	494	495	496	498	499	501	502	503	76	880	881	882	882	883	883	884	884	885	885
32	505	506	507	509	510	511	513	514	515	517	77	886	887	887	888	888	889	889	890	891	891
33	518	519	521	522	523	525	526	527	528	530	78	892	892	893	893	894	894	895	896	896	897
34	531	532	534	535	536	537	539	540	541	542	79	897	898	898	899	899	900	900	901	902	902
35	544	545	546	547	549	550	551	552	553	555	80	903	903	904	904	905	905	906	906	907	907
36	556	557	558	559	561	562	563	564	565	567	81	908	909	909	910	910	911	911	912	912	913
37	568	569	570	571	572	574	575	576	577	578	82	913	914	914	915	915	916	917	917	918	918
38	579	580	582	583	584	585	586	587	588	589	83	919	919	920	920	921	921	922	922	923	923
39	591	592	593	594	595	596	597	598	599	601	84	924	924	925	925	926	926	927	927	928	928
40	602	603	604	605	606	607	608	609	610	611	85	929	929	930	930	931	932	932	933	933	934
41	612	613	614	616	617	618	619	620	621	622	86	934	935	935	936	936	937	937	938	938	939
42	623	624	625	626	627	628	629	630	631	632	87	939	940	940	941	941	942	942	943	943	944
43	633	634	635	636	637	638	639	640	641	642	88	944	945	945	946	946	946	947	947	948	948
44	643	644	645	646	647	648	649	650	651	652	89	949	949	950	950	951	951	952	952	953	953
45	653	654	655	656	657	658	659	659	660	661	90	954	954	955	955	956	956	957	957	958	958
46	662	663	664	665	666	667	668	669	670	671	91	959	959	960	960	960	961	961	962	962	963
47	672	673	673	674	675	676	677	678	679	680	92	963	964	964	965	965	966	966	967	967	968
48	681	682	683	683	684	685	686	687	688	689	93	968	968	969	969	970	970	971	971	972	972
49	690	691	692	692	693	694	695	696	697	698	94	973	973	974	974	975	975	975	976	976	977
50	699	699	700	701	702	703	704	705	705	706	95	977	978	978	979	979	980	980	980	981	981
51	707	708	709	710	711	711	712	713	714	715	96	982	982	983	983	984	984	985	985	985	986
52	716	716	717	718	719	720	721	721	722	723	97	986	987	987	988	988	989	989	989	990	990
53	724	725	725	726	727	728	729	730	730	731	98	991	991	992	992	993	993	993	994	994	995
54	732	733	734	734	735	736	737	738	738	739	99	995	996	996	996	997	997	998	998	999	999
N	0	1	2	3	4	5	6	7	8	9	N	0	1	2	3	4	5	6	7	8	9

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CHART 10-3

MULTIPLE DECAY WORKSHEET

Item No.	Operation	Value
1	Record Initial Observed Intensity (R/Day)	
2	Record Initial Time (Days or Hours Since Zero Hour)	
3	Record Second Observed Intensity (R/Day)	
4	Record Second Time (Days or Hours since ZERO Hour)	
5	Divide Item 1 by Item 3 (1 ÷ 3)	
6	Take logarithm of Item 5	
7	Divide Item 4 by Item 2 (4 ÷ 2)	
8	Take logarithm of Item 7	
9	Divide Item 6 by Item 8 (6 ÷ 8) This is a.	
10	Record Desired Intensity (R/Day) Normally 0.1	
11	Divide Item 3 by Item 10 (3 ÷ 10)	
12	Take logarithm of Item 11	
13	Take logarithm of Item 4	
14	Multiply Item 13 by Item 9 (13 x 9)	
15	Add Item 12 and Item 14 (12 + 14)	
16	Divide Item 15 by Item 9 (15 ÷ 9)	
17	Take anti-log of Item 16. This is the time in days or hours, FROM ZERO HOUR, when the intensity assumed in Item 10 will be reached.	

Note: Use consistant time units in Item 2 and 4.

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TRAINING OUTLINE NO:	11
LECTURE:	Preparation of Instrument Calibration Curves.
TIME:	Fifty (50) minutes.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	Any Algebra text; Paragraph 9.12, Radiological Defense Manual, Volume 1. (See Footnote*)
STUDENTS' REFERENCES:	None.
TRAINING AIDS REQUIRED:	Charts appended hereto.

1. It should be apparent by this time that the presence of high energy radiation can not be felt, tasted, smelled or heard by an individual. To detect the presence of and measure the intensity of radiation, we must rely on radiation detection instruments.

2. The types, operation, calibration and use of these instruments will be covered during later phases of instruction. Without going into a discussion of the "why" at this time, it is a fact that these instruments do not read, directly, the true intensity of the radiation which they measure. Because of this fact we must determine the true value of the readings observed on an instrument and this process is called instrument calibration. The need for instrument calibration may be illustrated by the following example.

(INSTRUCTOR - REPRODUCE CHART 11-1)

A properly functioning instrument placed at Point A will read, say, 7.5 R/Day, and if the same instrument is placed at Point B, it probably will read about 1.8 R/Day. If we take a different instrument and place it at the same two points, A and B, the readings obtained will be different from both the true values and the values obtained with the first instrument.

3. This situation is undesirable since we want to be able to take any instrument, go to Point A and obtain the correct reading of 8.0 R/Day. To calibrate instruments, we compare their observed readings against a source of radiation; the intensity of which radiation is always constant

*A Victoreen 263A G-M Survey Meter should be demonstrated to aid the students in understanding how calibration curves fit into the general picture of radiological defense work.

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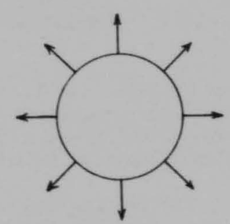
and reproducable. The difference between the observed instrument values and the true values can then be determined and thereafter applied as a correction factor to that particular instrument.

4. To find a source of radiation, the intensity of whose radiation is always constant and reproducable, is not difficult. Gamma radiation from the element Radium has been chosen as a standard for instrument calibration work. Some discussion of the behavior of radiation from a radioactive source must be given, however, before an intelligent discussion of calibration curves can be undertaken.

5. Radiation from a radioactive source travels in all directions from that source in this manner:



6. The intensity of this radiation at any point is found to be related to

a. The quantity of radioactive material present.

b. The distance away from the point at which the radioactive material is located. We find also that as we get farther away from a source, the intensity of radiation falls off very rapidly to an insignificant value. The mathematics of this relationship is best illustrated by means of a chart.

(INSTRUCTOR - REPRODUCE CHART 11-2)

7. The equation

$$I = \frac{CM}{D^2}$$

is a formula which we use for calibration work to calculate the true value of radiation intensity. Each term in the formula is defined as follows:

a. I is the radiation intensity at any point A and is (Refer to Chart 11-2) expressed in any units which we choose. These units are normally R/Day.

b. C is a constant the numerical value of which depends on the units in which we wish our answer expressed. If I is in R/Day the value

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of C will usually be 0.024. Pertinent values of C are shown in Chart 11-3.

c. M is the weight of the radium source which we use as a standard. This weight is expressed in milligrams, to the nearest hundredth of a milligram. A typical source would be 57.38 mg. in weight. The larger this source, the greater is the intensity of radiation therefrom.

d. D is the distance between the radium source and point A. This distance is normally expressed in yards but other units may be used if C is changed accordingly. It is of interest to note how radiation intensity vaires with distance since distance is our best protection against radiation hazards from an atomic bomb. The following chart will illustrate the point clearly.

(INSTRUCTOR - REPRODUCE CHART 11-4)

Thus we see that by increasing the distance between a source and ourselves from 1 yard to 4 yards causes a decrease in the radiation intensity to 1/16 of its value at 1 yard.

8. Actual instrument calibration work is carried out on a "calibration course" with a radium source whose size is known. This chart indicates how typical calibration course might look.

(INSTRUCTOR - REPRODUCE CHART 11-5)

9. Instrument calibration procedure is carried out in the following manner:

a. A data sheet similar to the following is prepared.

(INSTRUCTOR - PASS OUT CHART 11-6)

b. The radium source is placed at zero point and its weight, in milligrams (mg), recorded.

c. Instrument is placed in operation and, beginning at the marking most distant from the source and working toward the source, readings are obtained. We start at the outer edge because the radiation intensity is low and there is no danger of damaging the meter by running the needle off scale.

d. Readings are obtained for each scale of the instrument. There should be a minimum of six readings per scale; these readings to be spread evenly over the scale. The scale is normally a 1-20 scale.

e. Each reading, with the distance from the source at which the reading was obtained, is recorded.

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f. The actual radiation intensity at each point where readings were obtained is calculated by means of our formula

$$I = \frac{CM}{D^2}$$

g. Finally we come up with a set of data which might look like these

(INSTRUCTOR - REPRODUCE FOLLOWING TABLE)

SIZE OF SOURCE - 256.00 Mg

No. 1 Scale Reading	No. 2 Scale Reading	Yards From Source	Calculated Intensity (R/D)
18.25		1.0	0.59
14.80		1.25	0.38
11.90		1.5	0.26
9.50		1.75	0.19
7.75		2.0	0.15
4.30		3.0	0.07
2.30	17.30	4.0	0.04
1.50	12.50	5.0	0.02
	9.50	6.0	0.016
	7.80	7.0	0.012
	6.50	8.0	.009
	5.00	9.0	.007
	4.10	10.0	.005
	3.20	11.0	.004
	2.80	12.0	.003

C = .024

and we are ready to produce a calibration curve.

10. A detailed mathematical investigation of curves will not be made. Let us consider a curve as an unbroken line composed of a very large number of individual points and each point having some definite value with respect to two perpendicular axes.

(INSTRUCTOR - REPRODUCE CHART 11-7)

11. On the chart we see that Point A has a definite value with respect to the X-axis and with respect to the Y-axis. Point B has definite values also. If we obtain several points and plot them in proper relation to the X and Y axes we may simply draw a smooth continuous curve through all points since all the points are related to one another, and say that this curve represents the relationship between all points.

(INSTRUCTOR - MODIFY CHART 11-7 TO LOOK LIKE CHART 11-8. DO NOT INCLUDE THE DOTTED PORTIONS AT THIS TIME)

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Specifically, this means, as shown by Chart 11-8, that all points on the curve satisfy the general mathematical relationship which points A, B, C, D, and E do. We can use this type of curve when we know the y value of a point, to determine what the x value of the point is. This

(INSTRUCTOR - ADD DOTTED LINES TO CHART 11-8)

is what we need for our calibration curves.

12. Since these curves are to be our aids in the matter we may assign values to the axes as suits our inclination. It is customary to assign the horizontal (x) axis for measuring true radiation intensity values while the vertical (y) axis is used for instrument readings, with convenient values assigned thereto. Graph paper is used to plot the curve. It is well to point out here that several curves may be plotted on one piece of paper with two or three scales for one axis. This will be the case with our sample data. Now, referring to these data, we see that the one vertical scale for instrument readings will have to cover a range from somewhere around 1.0 to somewhere over 18.25. 0 to 20 is a convenient choice. For the horizontal scales, true radiation intensity, two selections must be made; one for each instrument scale. For Scale No. 1 a choice of 0-0.6 R/Day is obvious, while Scale No. 2 will nicely fit a 0-0.05 R/Day subdivision. These scales are marked in and each point plotted from the data. When all the points from one scale have been plotted a smooth curve should be drawn and titled. This procedure is then repeated for the second scale.

(INSTRUCTOR - WORK OUT PROCEDURE FROM DATA AND DRAW CURVES TO ROUGH SCALE ON BOARD)

13. These curves are used to tell us the true value of an instrument reading. For example - if we have an instrument set on the No. 1 scale and obtain a reading of 10, we refer to the proper curve; locate 10 on the vertical axis, go horizontally right until the curve for No. 1 scale is intercepted, drop vertically to the x axis and read our answer as 0.36 R/Day. This figure is the true radiation intensity.

Are there any questions?

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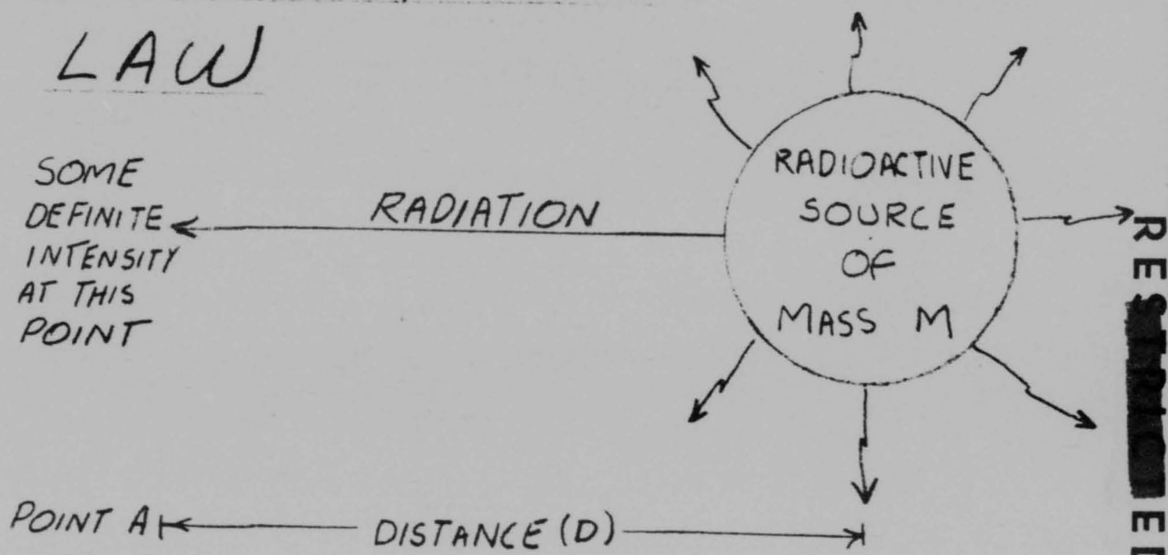
INVERSE SQUARE LAW

CHART II-2



INTENSITY AT A IS PROPORTIONAL TO MASS OF SOURCE AND INVERSE SQUARE OF DISTANCE

$$I \propto \frac{M}{D^2}$$

OR

$$I = \frac{CM}{D^2}$$

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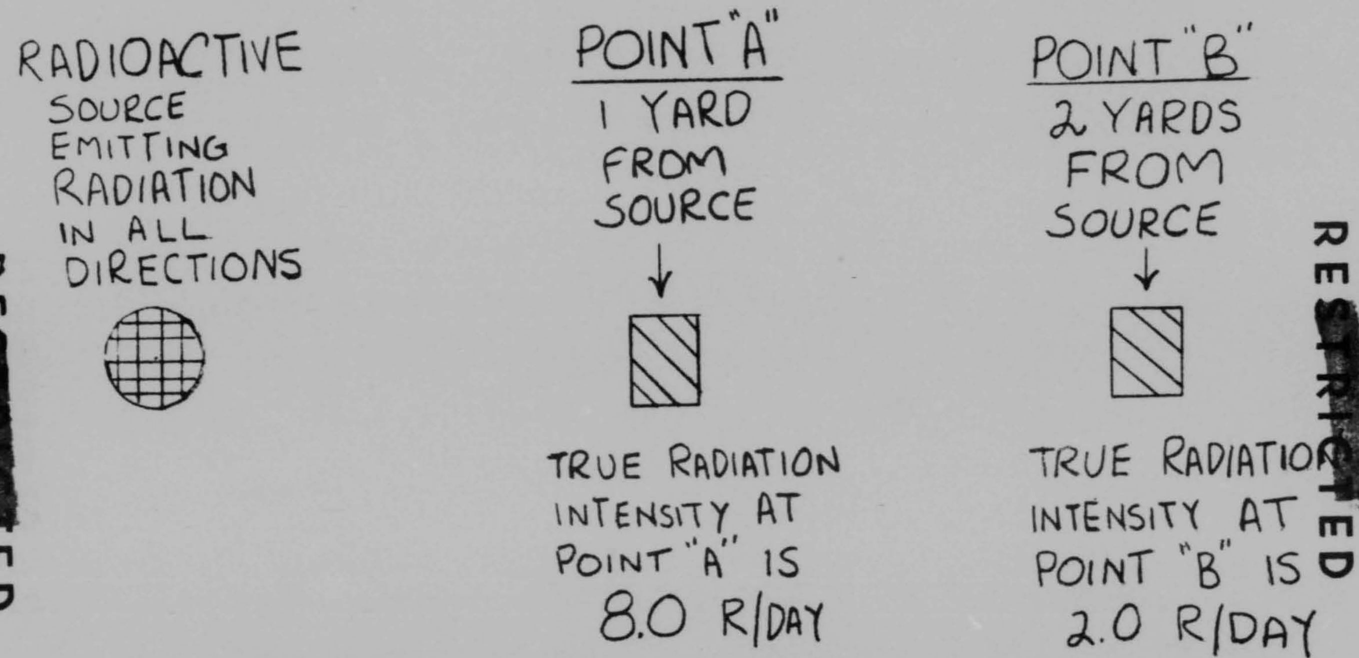
CHART 11-1



INTENSITY OF RADIATION - EFFECT OF DISTANCE

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CHART 11-3

VALUES FOR C

When D Is In	Use As C	To Get I In
Yards	.024	R/Day
Yards	24	MR/Day
Yards	1	MR/Hour
Feet	.0026	R/Day
Feet	2.6	MR/Day
Feet	1.11	MR/Hour
Centimeters	8.4	R/Day
Centimeters	8400	MR/Day
Centimeters	350	MR/Hour

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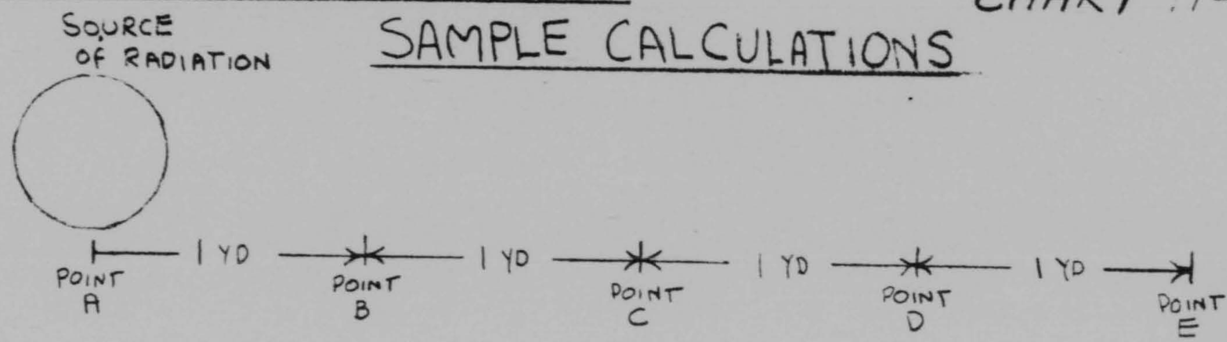
INVERSE SQUARE LAW — SAMPLE CALCULATIONS

CHART 11-4



$$I_{(AT\ B)} = \frac{CM}{(1)^2} = CM$$

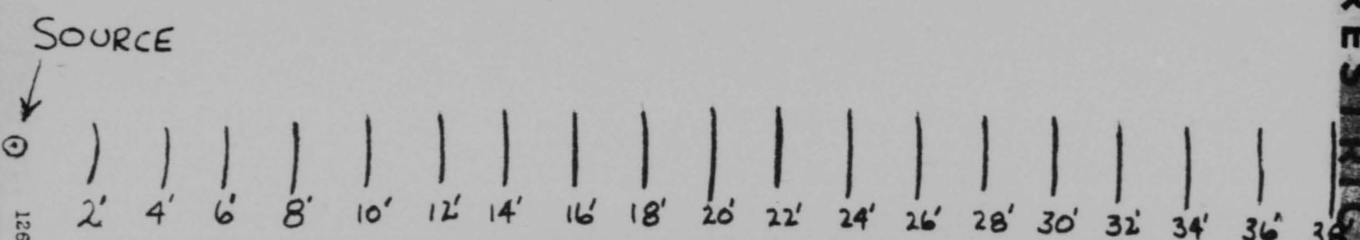
$$I_{(AT\ C)} = \frac{CM}{(2)^2} = \frac{1}{4} CM$$

$$I_{(AT\ D)} = \frac{CM}{(3)^2} = \frac{1}{9} CM$$

$$I_{(AT\ E)} = \frac{CM}{(4)^2} = \frac{1}{16} CM$$

LAYOUT OF INSTRUMENT CALIBRATION COURSE

CHART 11-5



DISTANCE MARKERS

1. LAID OUT ON FLAT SURFACE
2. MARKS ARE MEASURED FROM CENTER OF SOURCE.

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CHART 11-6

CALIBRATION DATA SHEET

Meter No.________________________ Date______________________

Type of Meter____________________ Wt. of Source_____________MG.

METER READING			DISTANCE FROM SOURCE IN---	CALCULATED INTENSITY IN---
Scale-------	Scale-------	Scale-------		

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CHART 11-7

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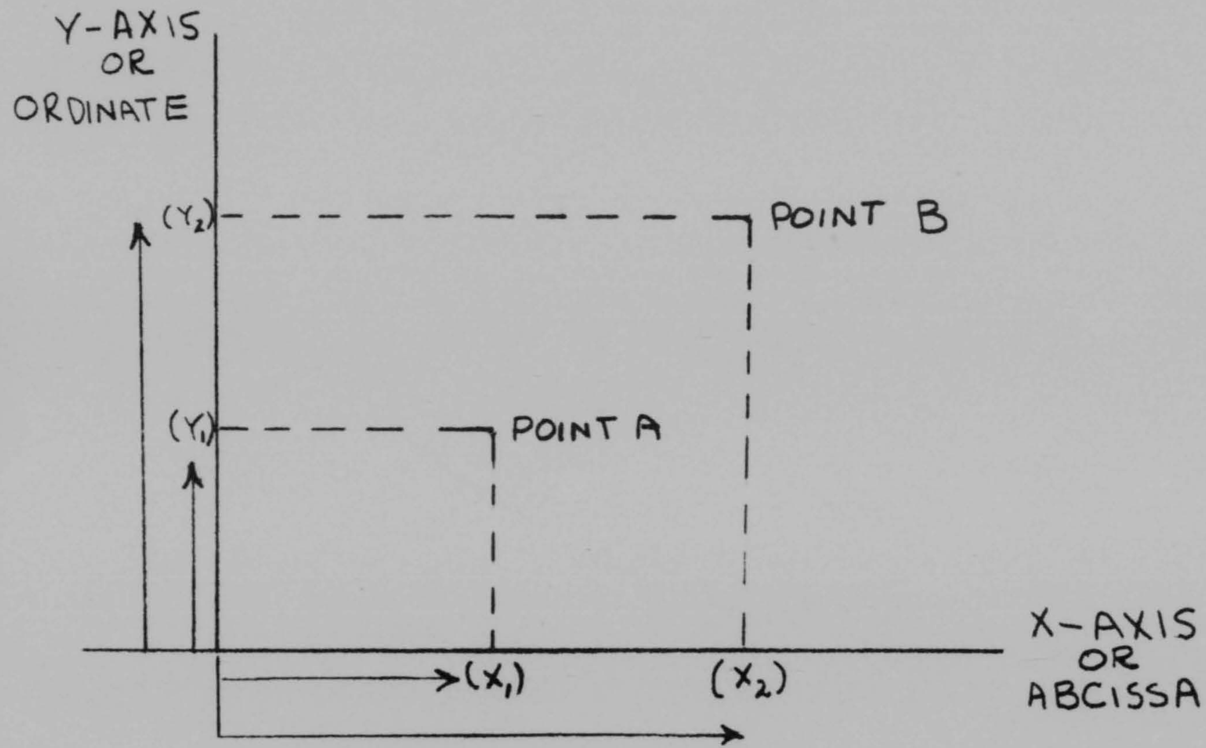

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COORDINATE SYSTEM

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CHART 11-8

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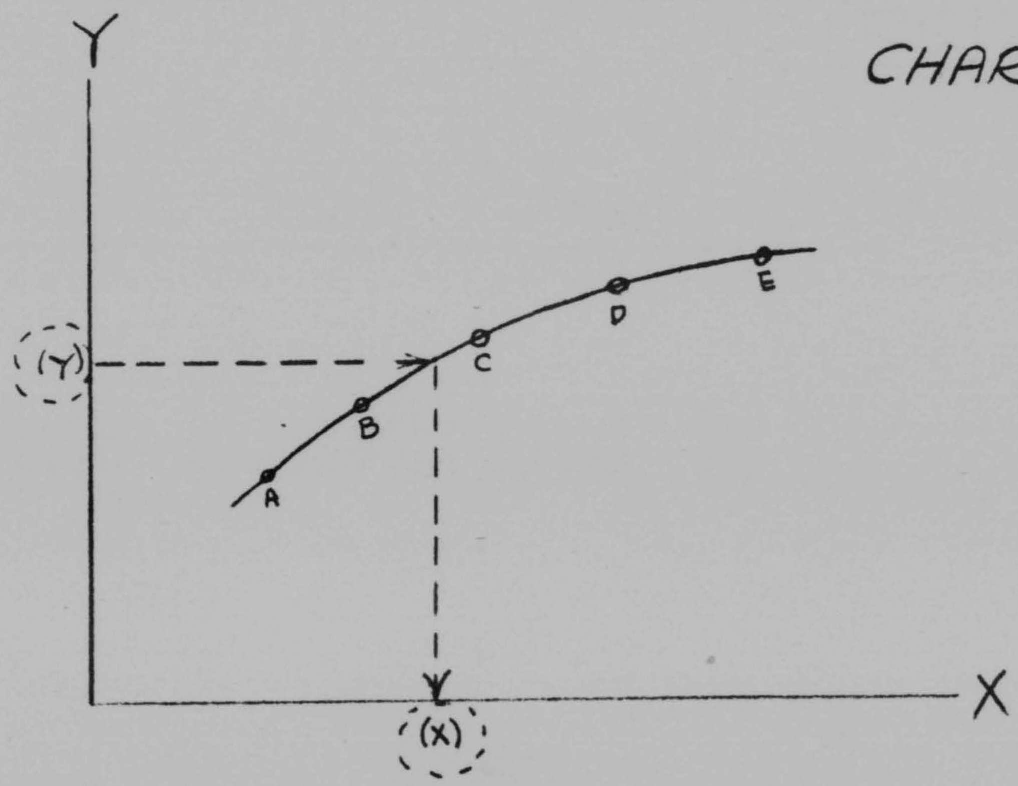

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TYPICAL CURVE

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TRAINING OUTLINE NO:	12
CLASS EXERCISE:	Student Preparation of Instrument Calibration Curves.
TIME:	Fifty (50) minutes.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	Training Outline #11. (See Footnote*)
STUDENTS' REFERENCES:	Notes from Training Outline #11 period.
TRAINING AIDS REQUIRED:	Scratch paper, graph paper, colored pencils, mimeographed data sheets (Chart 11-6 from Training Outline #11) and rulers.

1. This period is devoted to a class exercise wherein each student will plot a typical calibration curve for a 263A Geiger meter. The following procedure will be followed:

a. Pass out scratch pads, graph paper, colored pencils and data sheets to the students.

b. Instructor will make one sample intensity calculation and have students make all others. Use the equation

$$I = \frac{CM}{D^2}$$

with C = 1, M = 53.5 mg and D in yards so that I will be in units of mr/hr

Ex. I at 2 yds

$$I = \frac{(1)\ (53.5)}{(2)^2} = 13.4 \text{ mr/hr}$$

*This period should be conducted as a group performance exercise. The instructor should outline the steps to be followed and have each student complete one step before proceeding to the next. Each student should be provided with a straight edge, 3 colored pencils, one or two sheets of rectangular coordinate paper, scratch paper and two or three drawing curves should be available for use by the class. The calibration course data should be presented in tabular form on the blackboard, a chart or a mimeographed sheet. Attached as Chart No. 12-1 is the calibration curve plotted from these data, and is for use by the instructor in grading student work.

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2. When the students have completed the calculations, the instructor will call off the correct values as shown in Chart No. 12-2.

3. Instructor will then have students rule off graph paper with the y-axis as the scale readings and with the x-axis as the radiation intensity. Three scales will be used for the x-axis. These scales should be numbered as shown on Chart No. 12-1.

4. The students should then be instructed to plot the points for each scale, using a different colored pencil for each scale, and draw a smooth curve through each.

5. Finally the calibration curve should be labeled, turned in and graded for accuracy and neatness.

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CHART 12-1

CALIBRATION CURVE

19 MAY 1949

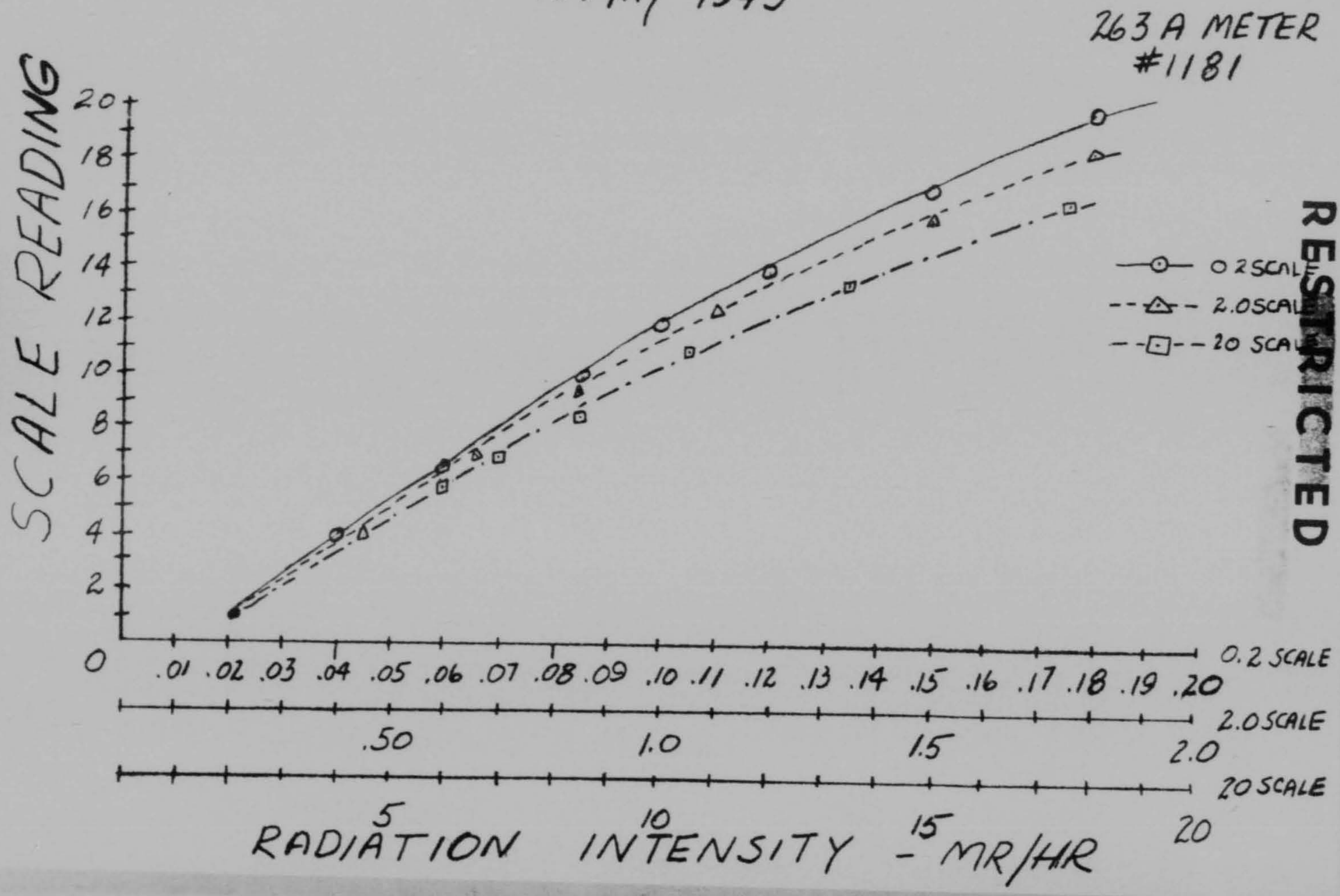

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CHART 12-2

CALIBRATION DATA SHEET

Meter No. 1181 Date 19 August 1948

Type of Meter 263A Wt of Source 53.50 mg.

Meter Reading			Distance From Source in Yards	Calculated Intensity in MR/Hr*
Scale .2	Scale 2.0	Scale 20		
		16.5	1 3/4	(17.5)
		13.5	2	(13.4)
		11.0	2 1/4	(10.5)
		8.5	2 1/2	(8.5)
		7.0	2 3/4	(7.0)
		6	3	(5.9)
		2.5	4	(3.3)
		1	5	(2.1)
	18.5		5 1/2	(1.8)
	16.0		6	(1.5)
	12.5		7	(1.1)
	9.5		8	(.84)
	7.0		9	(.66)
	4.0		11	(.44)
	1.0		16	(.21)
20			17	(.18)
17			19	(.15)
14			21	(.12)
12			23	(.10)
10			25	(.085)
6.5			30	(.059)
4			35	(.04)

* These calculated intensity values are for use in grading student work.

C = 1

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TRAINING OUTLINE NO: 13

LECTURE: Principles of Radiation Detection Instruments.

TIME: One (1) hour.

PLACE: Classroom

INSTRUCTORS REFERENCES: "All Hands", 1 July 1946, Navy Department; Paragraphs 9.01-9.12, Radiological Defense Manual, Volume 1; Chemical School Memo 202, 22 June 1948; Chapter 17, AFRTC Manual 52-355-1, Dept of the Air Force, May 1949; "Medical Aspects of Nuclear Energy", AFSWP, NME, 1949.

STUDENTS' REFERENCES: None.

TRAINING AIDS REQUIRED: Charts appended hereto.

1. The detection and measurement of high energy radiation depends entirely upon the proper use of suitable instruments. Without instruments even intense radiation fields will not be discovered and irreparable injury to personnel may result. It is, therefore, of utmost importance that all persons making radiation measurements have a thorough understanding of the principles of operation and of the limitations of the available instruments. Furthermore, an individual must interpret meter readings in terms of the specific instrument used. Dangerous errors can easily be made by an individual ignorant of the principles incorporated into the instrument design.

2. Excepting photographic film all detecting devices function by measuring the ionization produced in gases by high energy radiation passing through the gases. It is well, here, to repeat that ionization is a process wherein orbital electrons of the gaseous atoms are ejected from the neutral atoms by high energy radiation passing through their orbits, whereupon these ejected electrons fly over and arbitrarily attach themselves to other neutral atoms. As a result we have two electrically charged atoms where there were two electrically neutral atoms to begin with. The atom from which the electron was ejected, is left with a positive electrical charge since one of its positively charged protons no longer has a negatively charged electron to balance it. The atom to which the ejected electron arbitrarily attached itself becomes negative since it now has one excess negatively charged electron. The importance of this situation lies in the fact that electrically charged atoms are affected by magnetic and electrical fields whereas neutral atoms are not.

3. In the case of the horseshoe magnet, one pole of the magnet is called the positive pole while the other pole is known as the negative

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pole. Now is two horseshoe magnets have their poles touching, a curious thing happens. If positive poles of the two magnets are placed together there is a strong repulsive force exerted between the two poles, whereas if a positive pole of one magnet is placed to a negative pole of the other magnet there is a strong attractive force exerted between the two poles. This illustrates the fact that like charges repel and unlike charges attract. The concept of electrical fields is not so apparent as that of magnetic fields but both act in the same manner.

4. These facts are of interest to us because electrical fields can be used to make ionized (charged) atoms move in any desired direction or with any desired velocity. When the ionized atoms, formed in a gas by high energy radiation, are subjected to an electrical field, they will move apart in opposite directions. The negatively charged atoms will move toward the positively charged anode (positive plate) and the positively charged atoms will move twoard the negatively charged cathode (negative plate).

(INSTRUCTOR - REPRODUCE CHART 13-1)

When these ions reach the plates each negatively charged atom will give up its spare attached electron. These spare electrons go into the anode (positive plate). The positively charged atoms simply pile up at the cathode, however.

(INSTRUCTOR - REPRODUCE CHART 13-2)

From the plate the spare electrons are made to travel through a circuit to the cathode (negative plate) where they recombine with the positively charged atoms to become neutral atoms once more. The flow of electrons in a circuit generates an electric current which may be measured with a meter. The rate of flow of the electrons in the circuit determines how large an electrical current is generated. Likewise the rate of flow of the electrons in the circuit is determined by the intensity of the high energy radiation which ionized the atoms in the first place. Therefore, it may be seen that there is a definite relationship between the intensity of radiation and the amount of ionization which it produces. This relationship is the basis of all radiation detection instruments.

5. One type of instrument we call the Geiger-Mueller or Geiger Counter Instrument.

6. A Geiger counter is constructed essentially in the manner shown on the following chart.

(INSTRUCTOR - REPRODUCE CHART 13-3)

The counter consists of two plates; the cathode which is a metal cylinder and the anode which is a fine metal wire inside the cylinder. These two plates are separated and surrounded by an inert gas under low pressure; the entire assembly being enclosed by a sealed glass envelope. By means of a high voltage battery the plates are kept charged and a very strong electrical field exists between the two plates. When high energy radiation penetrates the glass envelope and ionizes the gas therein, negative ions flow to the anode and for a fraction of a second the circuit is complete. The source of high voltage causes an instant surge of heavy current, the mechanical register indicates a pulse and a click is heard in the speaker. The large resistor in the circuit then cuts the current flow to such a small value that the gasious ions are no longer attracted to the plates. The circuit is then broken, the instrument goes dead for a very short instant while the electrical field between the two plates is reestablished and then the process is repeated. Each time this cycle occurs we get appulse or click on the indicating portion of the meter, and the meter is said to have "fired".

7. The greater the intensity of the radiation, the closer together these ionizing "bursts" occur and the greater will be the number of pulses or clicks obtained. We can approximate the intensity of the incident radiation by the meter reading obtained or the number of clicks counted. Further, we can place screens around the thin glass envelope and filter out beta particles so that only gamma radiation will be measured. Alpha particles are not normally measured since they will not penetrate even the thinnest of glass envelopes. Geiger counters are therefore used to measure only Beta and/or Gamma radiation of fairly low intensity.

8. Only low intensity beta and gamma radiation may be measured with Geiger counters because of the "dead instrument time" previously mentioned. With high intensity radiation so many counts are missed (while the instrument is "dead") compared to the number of counts counted (while the instrument is "alive") that the results become meaningless. Therefore, Geiger counters are not satisfactory for measuring radiation intensities greater than about 20 mr/hour (0.4 R/day).

9. Measurement of extremely high energy radiation is accomplished by means of ionization chamber instruments. These instruments make use of cylindrical containers (or chambers) in which the ionized atoms are collected on a plate and manipulated to set up a current in a circuit.

(INSTRUCTOR - REPRODUCE CHART 13-4)

10. Without delving into electronic circuits the principle of operation may be explained as follows:

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a. The meter circuit is fixed so that, when no ionization is occurring, the current passing through the vacuum tube is constant and the meter indicates zero.

b. Radiation causes ionization in the ionization chamber and negative ions go to the plate (anode).

c. These negative ions cause a current flow in the ionization current circuit. This flow affects the vacuum tube in the meter circuit.

d. The vacuum tube allows the meter circuit to become unbalanced and the meter registers the degree of unbalance.

e. By proper adjustment of all factors the meter can be made to measure the intensity of radiation passing through the ionization chamber.

11. It should be understood that there are no pulses in an ion chamber instrument and clicks cannot be heard. The readings are not, therefore, dependent on counting of pulses and these instruments have no "dead time". For this reason they are very accurate for measuring high intensities of radiation. Due to certain characteristics, however, they <u>are not</u> used to measure <u>alpha or beta</u> radiation but only <u>for gamma radiation</u>.

12. It is possible to measure up to several hundred R/Day with these ionization chamber instruments.

Are there any questions?

INSTRUCTOR'S QUESTIONS:

1. Geiger counters may be used to measure what two types of radiation?

2. What is the highest radiation intensity that can be measured with a Geiger counter?

3. What general principle do all detection instruments, except photo film, work on?

4. Ionization chambers may be used to measure what type of radiation?

5. Is a Geiger counter or ion chamber more accurate for measuring gamma radiation?

6. How high a radiation intensity may be measured with an ion chamber?

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EFFECT OF ELECTRIC FIELD ON CHARGED PARTICLES

CHART 13-1

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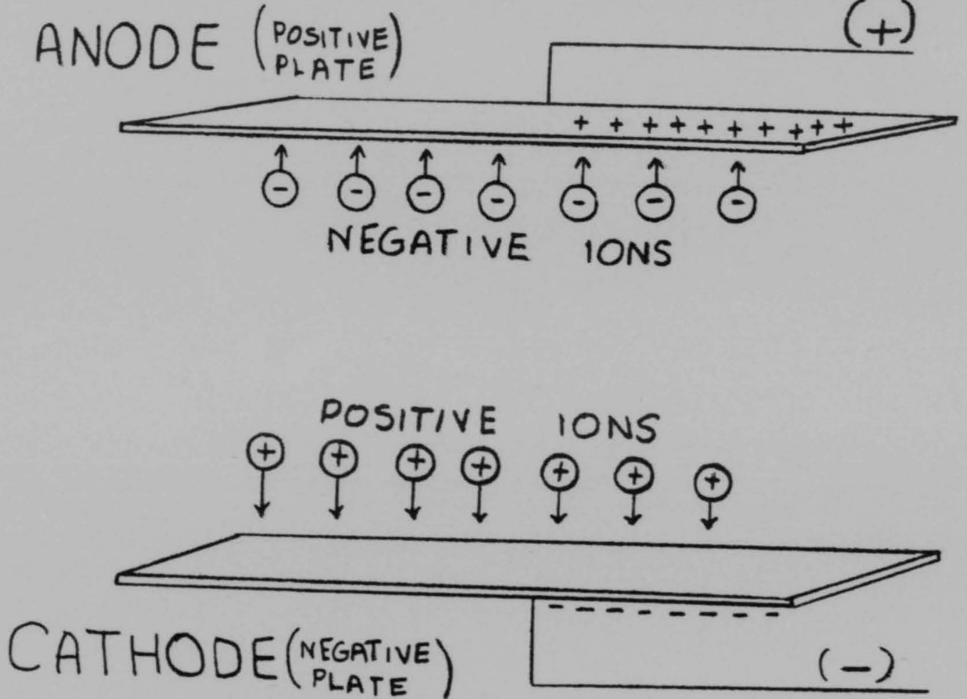

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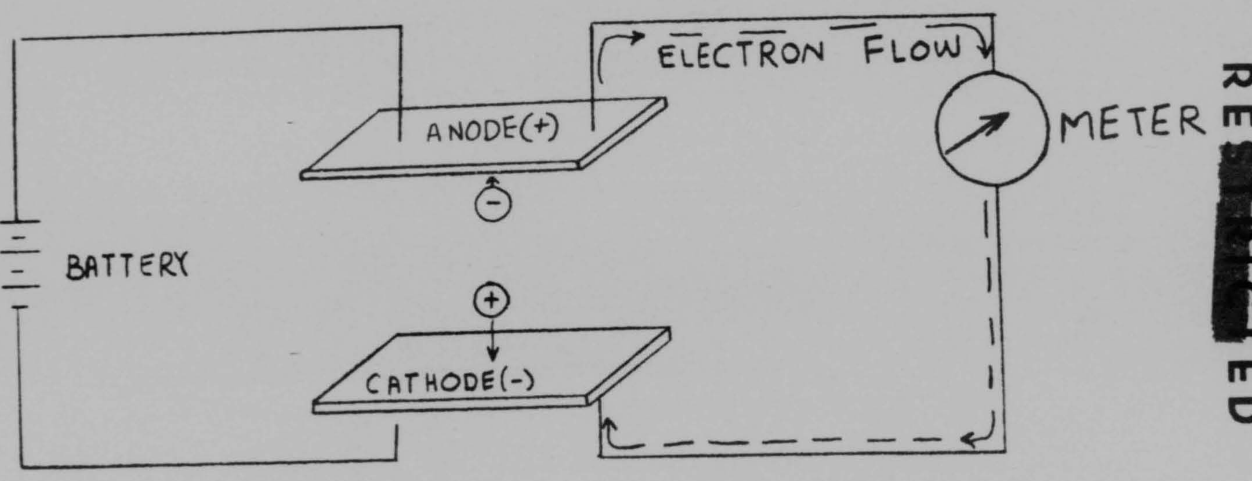
CHART 13-2



ELECTRON FLOW = ELECTRIC CURRENT

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SIMPLE GEIGER COUNTER

CHART 13-3

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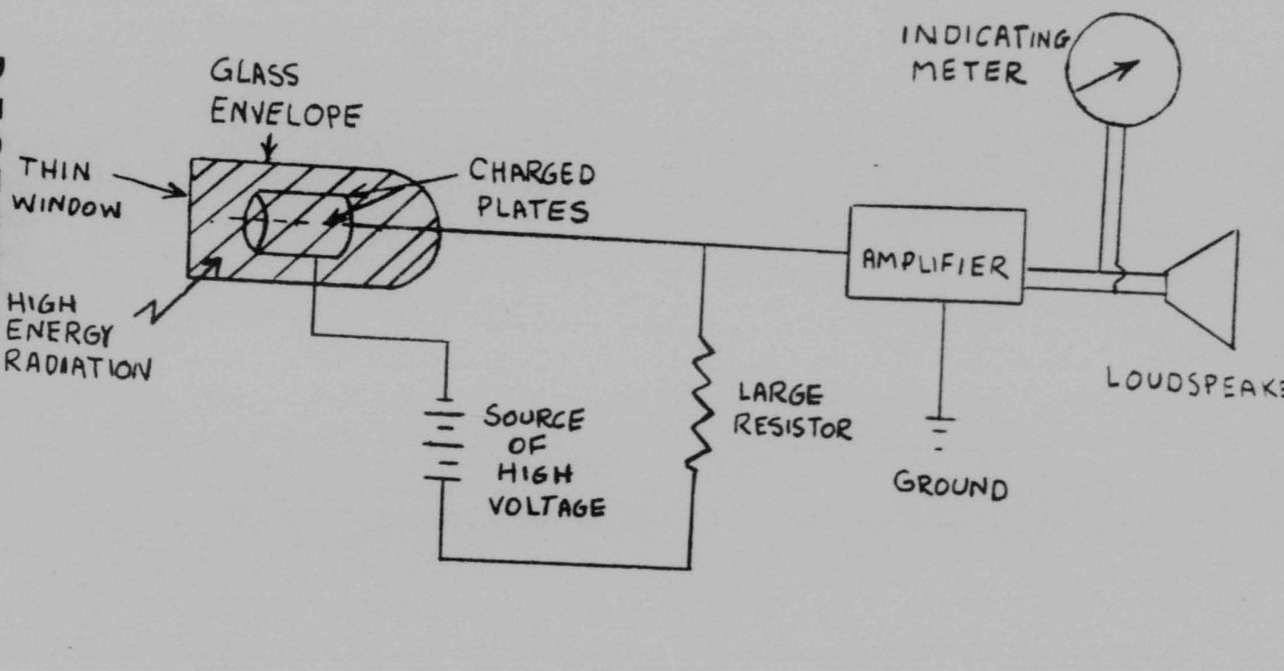

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IONIZATION CHAMBER CIRCUIT

CHART 13-4

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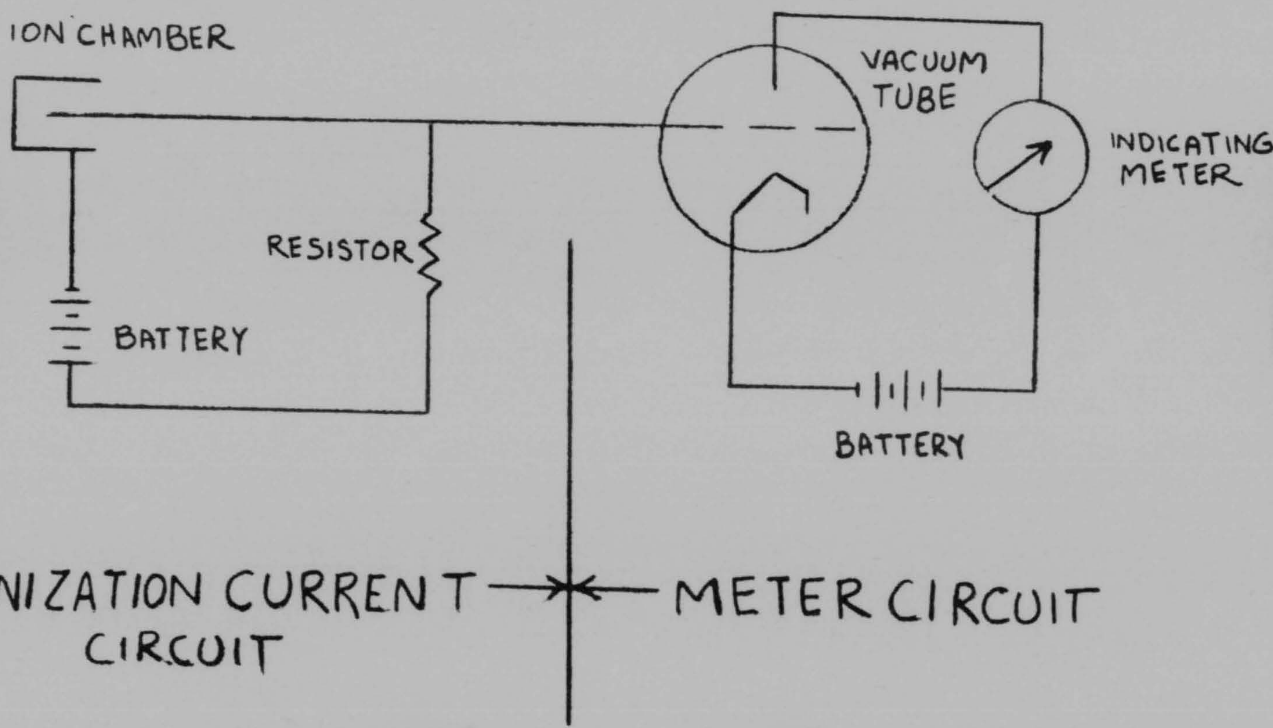

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TRAINING OUTLINE NO:	14
CLASS EXERCISE:	Operation of 263A G-M Survey Meter.
TIME:	One Hundred (100) minutes.
PLACE:	Classroom and outdoor area.
INSTRUCTORS' REFERENCES:	Technical Manual on 263A Survey Meter, Victoreen Instrument Company. (See Footnote*)
STUDENTS' REFERENCES:	None.
TRAINING AIDS REQUIRED:	Charts appended hereto, 263A G-M Survey Meters, radium source.

1. The 263A G-M Survey Meter is a portable instrument for measuring the intensity of beta and gamma radiation. The detecting device is a 900 volt Geiger tube. This tube is of thin wall glass construction to permit the measurement of beta particles.

2. Physical characteristics of the instruments are as follows:

(INSTRUCTOR DEMONSTRATE INSTRUMENT)

- a. Height - 10 inches.
- b. Width - 3 1/4 inches.
- c. Length - Exclusive of probe, 12 inches.
- d. Probe Opening - 2 x 2 1/2 inches.
- e. Beta Shield - 1/32 inch brass.
- f. Weight - 12 pounds.
- g. Finish - Gray enamel.
- h. Indicating Meter - 3 inch scale.
- i. Probe - 1 1/2 inches in diameter by 9 inches long and connected to the instrument by a four foot cable. Normally clamped to the front of the instrument case.

3. The principal parts of the meter are the case,

(INSTRUCTOR REPRODUCE CHART 14-1)

*This period is to be used to familiarize the student with the operation of a Victoreen 263A G-M Survey Meter. After each student has had an opportunity to operate the instrument under the supervision of an instructor, the second period should be devoted to obtaining average background counts and practicing an audio survey. Meter readings will be assumed correct for this period.

[redacted]

[redacted]

containing the batteries and wiring; a probe, containing the Geiger tube; an indicating meter, which is mounted in the case and indicates radiation intensities; a range switch which turns the meter on and allows selection from one of three intensity ranges (Range 0.2 is from 0 to 0.2 mr/hr, Range 2 is from 0 to 2 mr/hr and Range 20 is from 0 to 20 mr/hr; a phone jack which allows use of headphones, and an instrument calibration control adjustment screw which will not be tampered with. The probe has a beta shield which is closed when only gamma intensity is to be measured. Headphones are used to obtain background counts and to detect small changes in intensity which the meter will not differentiate. These instruments are quite sensitive and register the cosmic radiation which is continually bombarding all of us. This cosmic radiation causes a "count" or clicking noise to be heard in the headphones when no other radiation is present. This count is known as the background count and is fairly constant in any one area **THAT IS NOT CONTAMINATED WITH RADIOACTIVITY.**

4. Like all instruments, these meters are subject to ailments and should be checked before being used or calibrated. This check is very simple and is as follows:

a. Plug in earphones.

b. Turn range switch to the 20 scale, then to the 2 scale and then to the 0.2 scale. If the needle on the indicating meter swings to the 20 mark and stays there on any scale the instrument is defective and should be shut off at once.

c. If on the 0.2 scale an irregular clicking noise is heard and the needle on the indicating meter fluctuates between 0 and 5 the instrument may be satisfactory.

d. Readings of over 5 may indicate either the presence of radioactivity, instrument contamination or moisture in the instrument. This does not necessarily render the instrument useless but does indicate low sensitivity and therefore poor accuracy.

e. The beta shield should next be opened and the probe exposed to a source of strong light (i.e., sunlight if possible). A sharp increase in background count indicates that the Geiger tube is light sensitive and the instrument can only be used to measure gamma (with beta shield closed).

f. Constant needle fluctuation should not be taken as a sign of malfunctioning.

g. Following these checks one spot calibration check should

[redacted]

[redacted]

be made against some known source such as a luminous wrist watch which has previously been calibrated. Serious deviation indicates the recalibration of the instrument must be carried out.

5. Operating procedure is carried out in the following manner:

a. Background Measurement.

(1) Switch to 0.2 range. Meter should indicate less than 25% full scale.

(2) Plug in headphones.

(3) Observe a stop watch or wrist watch with sweep second hand. If a watch with luminous dial is used the body should be used as a shield between the watch and probe.

(4) Count the number of "clicks" in the phones for a one minute period. Repeat several times. The scale reading should be noted also for future reference.

b. Gamma Measurement.

(1) Close beta shield on probe and plug in earphones.

(2) Turn range switch to 20.

(3) Place instrument with probe in the location to be measured.

(4) If reading is less than 10% of full scale, switch to 2.0.

(5) If reading is still less than 10% of full scale, switcheto 0.2.

(6) Watch indicating meter for about 30 seconds to determine the average reading. This is very important on the 0.2 scale.

(7) Read the meter and record data.

c. Beta Measurement.

(1) Remove the probe from its brackets and place it in the desired location. This is very important in beta measurement.

(2) Repeat gamma measurement procedure outlined above but with beta shield open. Record reading. (This is beta

[redacted]

[redacted]

plus gamma reading.)

(3) Close beta shield and take gamma measurement with probe in the same location. Record reading. (This is gamma only reading).

(4) Beta intensity is obtained by subtracting reading (3) from reading (2).

d. Audio Survey.

(1) Decide upon the level of intensity above which a careful measurement should be made. It is recommended that 0.1 mr/hr be used.

(2) Plug in earphones.

(3) Switch to 0.2 range.

(4) Place a radium sample or other source of radiation at a distance to give the level of intensity selected in (1) above.

(5) Listen to the signal to become accustomed to the noise level and pulse repetition rate.

(6) Move the probe back and forth toward and away from the sample. Notice carefully the difference in the audio signal as the intensity is increased or decreased.

(7) Close your eyes and have someone move the sample a short distance.

(8) Try to reproduce the distance (4) above between the sample and the probe, within 10%, using only the audio signal as a guide.

(9) When (8) can be accomplished easily, audio surveys can be made with a degree of confidence and in much less time than in any other manner. Attempts have been made to cover a wide range of intensities in audio surveying but the one point comparison method is the only satisfactory one.

e. Recording Data. Many operations involving the measurement of radiation have been hampered by loss of information due to incomplete and improper recording of data. If data sheets are not provided, a monitor should make up his own before starting a survey. The following information must be recorded on each data sheet:

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(1) Date.
(2) Time.
(3) Place.
(4) Instrument model and serial no.
(5) Identification of source.
(6) Position of probe with respect to source.
(7) Position of beta shield.
(8) Position of range switch.
(9) Meter reading.
(10) Units of measurement.
(11) Background reading.
(12) Comparison standard reading.
(13) Identification of standard sample.

6. Those items which are the same for all measurements can be incorporated in the data sheet heading. The other items can be listed as column headings.

Are there any questions?

INSTRUCTOR'S QUESTIONS:

1. What types of radiation does the 263A Survey Meter detect?

2. What radiation intensity does the 0.2 Range of the 263A measure? The 2.0 Range? The 20 Range?

3. What is background count?

4. How is a Geiger tube checked for light sensitivity?

5. How do we differentiate between beta and gamma radiation with the 263A?

6. What is the procedure for making an audio survey?

The balance of the period will be devoted to obtaining background counts.

The second period will be devoted to practice audio surveys.

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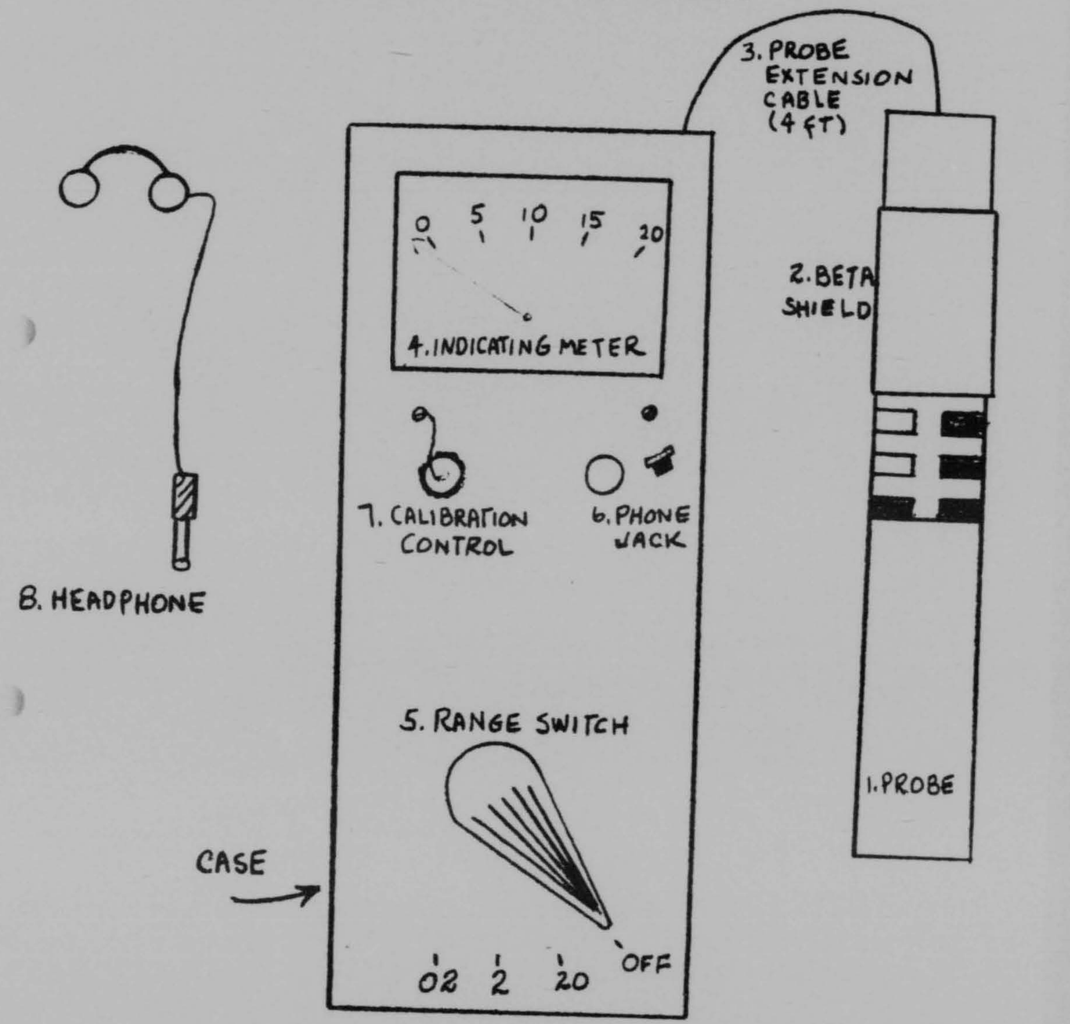
263A SURVEY METER CHART 14-1



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TRAINING OUTLINE NO:	15
EXAMINATION:	I
TIME:	One Hundred (100) minutes.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	Training Outlines 2 to 14, all previous references, Instructor's Answer Guide. (See Footnote*)
STUDENTS' REFERENCES:	Lecture notes from Training Outlines 2 to 14.
TRAINING AIDS REQUIRED:	Copies of Examination I, Copies of Chart 10-2.

<u>INSTRUCTIONS</u>:

1. Use of students' notes is permissible.

2. All questions can be answered in one short sentence or less.

3. Check your paper for completeness - there are <u>25</u> questions in this examination.

<u>QUESTIONS</u>:

1. What are isotopes?

____

____

2. All atoms (except Hydrogen 1) contain three kinds of particles. What are these three kinds of particles?

a.______________ b.______________ c.______________

3. The chemical nature of an atom is determined by one factor. What is this factor?

____

*Students should be permitted to use their notes. At completion of examination, the questions should be reviewed and the correct answers given.

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[redacted]

4. The necleus of an atom weighs about 1% less than it should. Why is this of interest to us?

____

____

5. The term "high energy radiation" is useful to us. Define this term.

____

____

6. There are many types of electro-magnetic radiation such as infra-red, ultra-violet and X-rays. In what one way are these types of radiation different?

____

7. Name four kinds of "high energy radiation". (Do not confuse with types of electro-magnetic radiation)

a.______________ b.______________

c.______________ d.______________

8. Radioactive isotopes spontaneously liberate energy. What is this process called?

____

9. Define the term "ionization".

____

____

10. What do nuclear reactions represent?

____

____

11. Three distinct things happen when a U-235 atom is struck by a neutron "bullet". What are these three happenings?

a.______________________________

b.______________________________

c.______________________________

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[redacted]

12. There are two types of neutron induced reactions. What are these two types?

a. ____________________

b. ____________________

13. What is meant by the term "critical mass"?

____

____

14. Following an atomic explosion, there is lasting radioactive contamination. This contamination comes from three sources. What are these three sources?

a. ____________________

b. ____________________

c. ____________________

15. What is meant by the term "fall-out"?

____

____

16. When an atomic bomb explodes there are three instantaneous effects. What are these three effects?

a. ____________________

b. ____________________

c. ____________________

17. What is the daily permissible tolerance dose of radiation?

____________________ R/Day

18. What is the equation

$$It^n = K$$

useful for?

____

____

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[redacted]

19. Why is it necessary to calibrate radiation detection instruments?

____

____

20. Calculate the radiation intensity at a point which is 10 yards from a 256.00 mg Radium source. C = .024

____

21. What two kinds of high energy radiation may be measured with a Geiger counter?

a. ____

b. ____

22. What is the highest radiation intensity that can be measured with a Geiger counter?

___________________________ mr/hr (approximate)

23. With the exception of film badges, all radiation detection instruments operate on one principle. What is this principle?

____

____

24. What kinds of high energy radiation can be measured with an ion-chamber instrument?

____

____

25. An atomic bomb explodes at 1200 hours on 15 July. Exactly 24 hours later a reading of 200 R/Day is obtained in one affected area. This same area reads 9 R/Day at 1200 hours on 27 July. When will this area read 0.3 R/Day? (Use attached worksheet)

[redacted]

TRAINING OUTLINE NO:	16
CLASS EXERCISE:	Student Calibration of 263A Survey Meters.
TIME:	One hundred and fifty (150) minutes.
PLACE:	Classroom and Instrument Calibration Course.
INSTRUCTORS' REFERENCES:	Paragraph 9.12, Radiological Defense Manual, Volume 1. (See Footnote*)
STUDENTS' REFERENCES:	Notes from Training Outlines No. 11, 12 and 14 periods.
TRAINING AIDS REQUIRED:	Data sheets, clip-boards, 263A Survey Meters, headphones, radium source, graph paper, rulers, colored pencils and scratch paper.

1. Students will draw equipment and assemble in the classroom. They will be briefed on the general procedure for obtaining data as outlined in Training Outline #11. The size of the radium source will be given. Data sheets should be passed out or drawn up. The following points on technique should be covered:

a. Calibration is done with the beta shield closed.

b. The instrument should be placed on the floor with the probe directly facing the source.

c. The center of the probe should be placed directly over the distance marker.

d. Each meter reading recorded should be the average reading obtained over a 30 second period.

*This exercise is based on the assumption that a gamma radium source is available and that a calibration course has been marked off prior to the start of the period. The size of the source available will determine the amount and sub-divisions of distance required. Too much emphasis cannot be placed on prior preparation for this period. Students should be able to draw instruments, proceed to the calibration course and begin obtaining readings at once. They should not be hampered by lack of distance markers or by poor placement of these markers. Specifically, markers should be so placed that one is available for each point at which a scale reading is desirable. Data should be taken for each of the three ranges and a set of three calibration curves prepared on the spot. These curves should be checked by the instructor for accuracy and graded.

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[redacted]

e. Care should be exercised that personnel do not come between the source and the probe. Likewise, luminous wrist watches should not be worn.

f. Readings obtained less than one inch from a source are meaningless.

g. Readings on the extreme ends of the scale are not accurate.

2. Following this, students should proceed to the calibration course, obtain readings and record data.

3. Finally, students should return to the classroom and prepare a calibration curve. This should be done as outlined in UGRD-14 with the plot being made of actual intensity vs scale reading and a smooth curve drawn, using a different color for each meter scale. This curve will be turned in for grading.

Any questions from students should be answered.

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TRAINING OUTLINE NO:	17
CLASS EXERCISE:	Operation of 247A Ion Chamber Survey Meter.
TIME:	Fifty (50) minutes.
PLACE:	Classroom and Outdoor area.
INSTRUCTORS' REFERENCES:	Instruction Manual on Model 247A Survey Meter, (Victoreen Instrument Company. (See Footnote*)
STUDENTS' REFERENCES:	None.
TRAINING AIDS REQUIRED:	Chart appended hereto; 247A Survey Meters, Radium Source.

1. The 247A Ion Chamber Survey Meter is a portable instrument for measuring the intensity of gamma radiation. The detecting device is a hermetically sealed ionization chamber which measures only gamma radiation.

2. Physical characteristics of the instrument are as follows:

(INSTRUCTOR - DEMONSTRATE INSTRUMENT)

a. Height - 13 inches.
b. Length - 10 1/3 inches.
c. Width - 5 1/3 inches.
d. Weight - 1.2 pounds.
e. Finish - Gray enamel.
f. Indicating Meter - 3 inch scale with 25 divisions.

3. The principal parts of the instrument are a case, containing the ion chamber, batteries and wiring; an indicating meter, mounted in the case; and controls which include a battery switch, a zero adjustment, and a range switch that allows selection of one of four intensity ranges as follows:

x1	-	0 to 2.5 mr/hr
x10	-	0 to 25 mr/hr
x100	-	0 to 250 mr/hr
x1000	-	0 to 2500 mr/hr

*This period is to be used to familiarize the student with the operation of a Victoreen 247A Ion Chamber Instrument. Each student should be "checked out" on its operation under the direct supervision of an instructor.

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4. Headphones are not used nor is it possible to measure beta with this instrument. The gamma sensitivity of the x1 range is comparable to the 2 range of the 263A G-M meter. Background count will not, normally, register on this instrument.

5. The 247A instrument is a fairly rugged device and little trouble should be encountered in its use. The most undesirable feature of the 247A lies in the fact that the needle must be rezeroed very frequently. Erratic fluctuations of the needle may be taken as a sign of malfunctioning. Prior to use a spot calibration check should be made.

6. Operating procedure is carried out in the following manner:

(INSTRUCTOR - REPRODUCE CHART 17-1)

a. Turn battery switch to "CHECK" position. Indicating meter should show a reading of 1.9 or greater. If lower than 1.8 batteries should be replaced.

b. Turn battery switch to "ON" position.

c. Turn range switch to "SENSITIVITY CHECK" position. The indicating meter should show a reading of 1.9 or greater If lower than 1.8 the instrument needs adjustment by a qualified technician.

d. Turn range switch to "ZERO CHECK". Indicating meter should show reading in the vicinity of zero.

e. Turn the zero adjustment knob until the meter reading is exactly zero.

f. Turn the range switch to the x1000 range. Place instrument in location to be measured.

g. If reading is less than 10% of full scale, switch to x100 range and on down until a reading is obtained. Wait 10-15 seconds and obtain the average reading.

h. Record the data.

7. These instruments should be handled with care and the switches turned gently. The battery switch has stop pins which limit its travel in both directions. If a battery switch is forced, these pins will shear off and the instrument rendered inoperative.

Are there any questions?

[redacted]

[redacted]

INSTRUCTOR'S QUESTIONS:

1. What types of radiation does the 247A survey meter detect?

2. What radiation intensity does the x1000 Range of the 247A survey meter measure? The x10 Range? The x1 Range? The x100 Range?

3. What range of the 247A survey meter is comparable to the 2 range of the 263A survey meter?

4. How is background count obtained with a 247A survey meter?

5. What adjustment must be frequently made when using the 247A survey meter?

6. Why must the battery switch of a 247A survey meter not be forced?

Balance of period is devoted to "checking out" students on the operation of the 247A.

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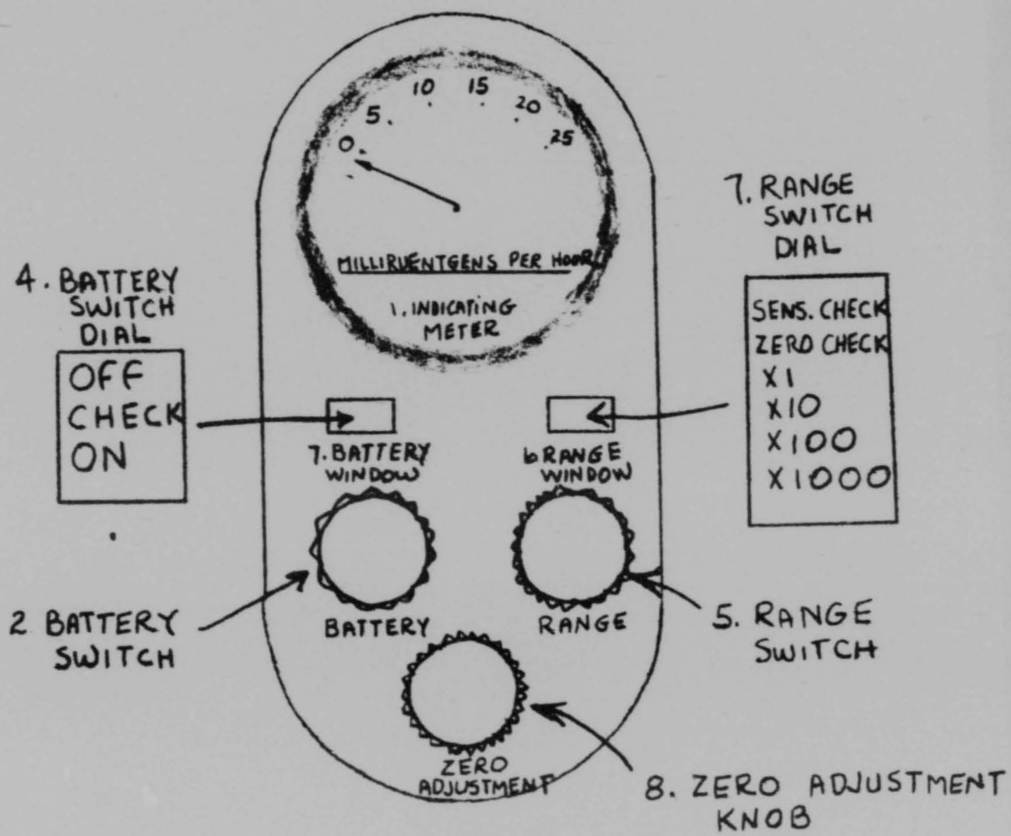
247A ION-CHAMBER SURVEY METER

CHART 17-1



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TRAINING OUTLINE NO:	18
CLASS EXERCISE:	Student Calibration of 247A Survey Meters.
TIME:	One hundred and fifty (150) minutes.
PLACE:	Classroom and Instrument Calibration Course.
INSTRUCTORS' REFERENCES:	Paragraph 9.12, Radiological Defense Manual, Volume 1. (See Footnote*)
STUDENTS' REFERENCES:	Notes from Training Outlines No. 11, 12, 14 and 16 periods.
TRAINING AIDS REQUIRED:	Data Sheets, clip-boards, 247A Survey Meters, radium source, graph paper, rulers, colored pencils and scratch paper.

1. Students will draw equipment and assemble in the classroom. They will be briefed on the general procedure for obtaining data as outlined in Training Outline No. 11 and 16. The size of the radium source is given and data sheets are prepared. The following points on technique should be covered:

a. The importance of constantly checking the zero of the instrument. Before any reading is recorded the zero should be checked.

b. The importance of placing the center of the indicating meter over the distance marker. Failure to do so will result in inaccurate readings since the ion chamber is directly beneath the meter.

c. The fact that the ion chamber has a diameter of over two inches and therefore readings taken a short distance apart are valueless. No two readings should be taken closer together than 2 inches.

2. Following this, students should proceed to the calibration course, obtain readings and record data.

3. Finally, students should return to the classroom and prepare a calibration curve as outlined in Course Outlines 12 and 16. This curve will be turned in for grading.

*This exercise is conducted in exactly the same manner as Training Outline No. 16. Two additional factors must be considered however; first that a 100 mg source is necessary to calibrate even 40% of the X1000 range (if a smaller sample is used no attempt should be made to calibrate the X1000 scale) and, second that the center of the dial should be placed over the distance marker in order that accurate results are obtained. It is essential that the instructor "dry run" this exercise prior to presentation to insure that distance markers are at satisfactory locations.

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TRAINING OUTLINE NO:	19
LECTURE:	Radiation Dosimetry.
TIME:	Fifty (50) minutes.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	Paragraphs 9.04-9.05, 9.12, 9.15-9.17, Radiological Defense Manual, Volume 1.
STUDENTS' REFERENCES:	None.
TRAINING AIDS REQUIRED:	Charts Appended hereto; pocket dosimeters, dosimeter charge box, film badges.

1. This period is devoted to a study of the equipment and methods used to determine the dose of external radiation which an individual receives in an area contaminated with radioactivity.

2. During a previous period the effect of radiation on the body was discussed and it was pointed out that 0.1 R/Day is the maximum allowable dose for personnel to receive at the present time. The question then arises as to how an individual knows when he has received 0.1 R/Day. To answer this question it is best to clarify and review the difference between "Radiation Intensity" and "Radiation Dosage".

3. "Radiation Intensity" may be compared to the velocity with which an automobile is traveling at any particular moment. In other words how fast or intense something is "right now". However, just because we may be going 60 miles per hour "right now" does not mean that we will cover 60 miles in the next hour. We may only drive 1 mile at 60 miles per hour and then stop. The distance which we cover may be compared to "Radiation Dosage". Thus, just as the distance which we travel in an automobile is a summation of all the small distances which we cover at various rates of speed so the radiation dose is a summation of all the small quantities of radiation which an individual absorbs in moving through areas of varying radiation intensity.

4. The Geiger meter and the ion-chamber meter which we have previously studied are rate or intensity meters. They tell what the radiation intensity at a point is right now. If we stay in that spot for a definite period of time it is possible to determine about what dose we will receive, (for example - a person in an area where a Geiger meter showed the radiation intensity to be 50 mr/hr would know that if he remained in that area for 2 hours he would receive a dose of about 100 mr), but in practice this is not the case since we move around continually through areas of greatly varying intensity. It is necessary to find some device which will act as

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a totalizer or adding machine to keep a running total of our dose. In practice two devices are used side by side to accomplish this task; the film badge and the pocket dosimeter. Each will be discussed.

5. The pocket dosimeter is a small ionization chamber which is contained in a case resembling a fountain pen. This dosimeter contains a charged metal fiber which becomes neutralized when ions are formed inside the case by radiation. The amount of radiation received by the instrument is proportional to the amount of neutralization of charge. The measuring portion of this instrument utilizes the principle of electricity wherein like charges repel each other. The ionization within the chamber neutralizes these charges so that the metal foil or fiber returns to its uncharged position. The pocket dosimeter does not require continuous external voltage for operation but, when discharged, must be recharged from an external source. One form of this instrument is shown on the following chart.

(INSTRUCTOR - REPRODUCE CHART 19-1)

The instrument is about the size of a large fountain pen. The conducting system in the dosimeter consists of two metal coated quartz fibers, each of which is bent into a U (C and D in the illustration). These two fibers are fused together at the end of the U and a simple optical lens system is focused at the end of one fiber (D in the illustration). Contained within the lens system is a transparent scale, graduated in milliroentgens, so that the movement of the movable fiber gives direct readings of radiation dosage received. A positive charge is placed on the fiber system and causes the fibers to diverge by mutual repulsion. Radiation causes ionization within the chamber which neutralizes this positive charge and allows the fibers to move back together. The protective cap on one end of the dosimeter has a glass window to allow light for illuminating the fiber and scale. When this cap is removed, a contact is exposed for charging the fiber system from a charging box. At the present time, dosimeters are built with several different ranges but the one which we will normally use has a range of 0 to 200 mr. These dosimeters are sufficiently strong to withstand the shock of normal human activity and are small enough to be worn comfortably for direct reading. Each individual entering a radioactive area wears a pocket dosimeter and periodically checks it to determine how closely he is approaching a tolerance dose (100 mr). Two additional points should be noted in connection with dosimeters:

a. Insulator Soak-In. When pocket dosimeters have not been used for some length of time (3-4 days) and are initially charged, the charge will leak away quite rapidly. After two or three rechargings this leak-away rate will decrease to a normal value of 1-20 mr per 24 hour period.

b. Calibration of Dosimeters. All dosimeters are slowly discharged by cosmic radiation. This leakage rate must be determined by charging a dosimeter, letting it sit for a 24 hour period and then determining the leakage rate. Dosimeters in good condition should not have a leakage rate in excess of 1-2 mr per hour. Finally it is wise to calibrate dosimeters periodically (say every two weeks) against a standard

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source. If a dosimeter is given a very hard blow (i.e. dropped on a concrete floor) it should be immediately recalibrated.

6. The film badge is a small piece of X-Ray film with a lead foil cross wrapped around it so that only the corners of the film are exposed and the entire unit wrapped in several layers of waterproof, lightproof paper. This is illustrated by the following chart.

(INSTRUCTOR - REPRODUCE CHART 19-2)

Upon exposure to radiation, the silver salt contained in the photographic film is converted to developable metallic silver. When the film is developed, the degree of darkness caused by the deposit of silver is proportional to the dosage of radiation received. By comparison with standard films (i.e. those which have been exposed to a known dosage) it is possible to determine the total dosage received. Most of the gamma radiation will pass completely through the uncovered portion of the film so that this uncovered portion of the film will record only the beta radiation. On the other hand the lead cross will stop all beta radiation and will deenergize the gamma radiation to such an extent that all the gamma radiation (and only gamma) will be recorded under the cross. Each person entering a radioactive area wears a film badge along with a pocket dosimeter. The reason for carrying a film badge is the fact that it is more accurate than a dosimeter, it differentiates between beta and gamma radiation, and it provides a permanent legal record to protect the government against fraudulent medical claims at some later date. It has the disadvantages that it is not direct reading and requires several hours for development and reading. For this reason it is necessary that an individual carry a pocket dosimeter in order that he may determine his dosage on the spot. Care must be exercised in the storage of unexposed film badges since they deteriorate with time and unfavorable condition of temperature and humidity. Personnel film badges are normally made to cover a dosage range of 50-4000 mr although it is possible to produce films which will measure much greater doses.

Are there any questions?

<u>INSTRUCTOR'S QUESTIONS</u>:

1. What is the difference between radiation intensity and radiation dosage?

2. What are two devices for measuring radiation dosage?

3. Essentially, what is a pocket dosimeter?

4. What source of power does a dosimeter require?

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5. What is the leakage rate of a good dosimeter?
6. Why do we use film badges?
7. Why do we use pocket dosimeters?
8. What is the purpose of the lead cross on a film badge?

Note to Instructor:

The balance of the period should be devoted to instructing students in the use of the dosimeter charge box.

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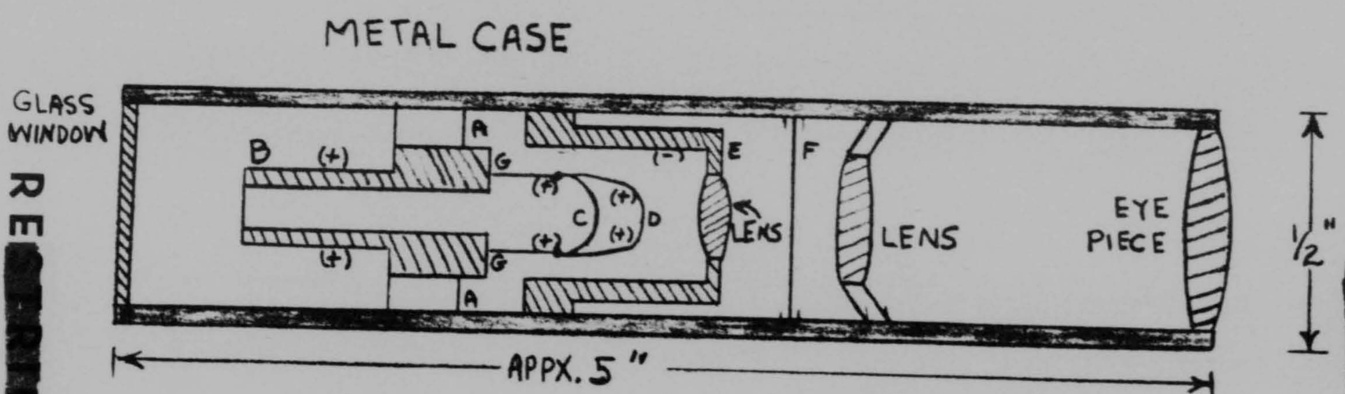
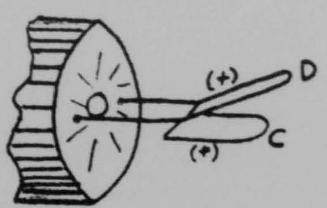
POCKET DOSIMETER

CHART 19-1



SIDE VIEW SHOWING ARRANGEMENT OF FIXED AND MOVABLE FIBERS



A - INSULATING RING
B - CHARGING ROD (HOLLOW TO ADMIT LIGHT FROM WINDOW)
C - FIXED HEAVY FIBER
D - MOVABLE LIGHT FIBER
E - METAL CYLINDER
F - TRANSPARENT SCALE
G - METAL SUPPORT FOR FIBERS

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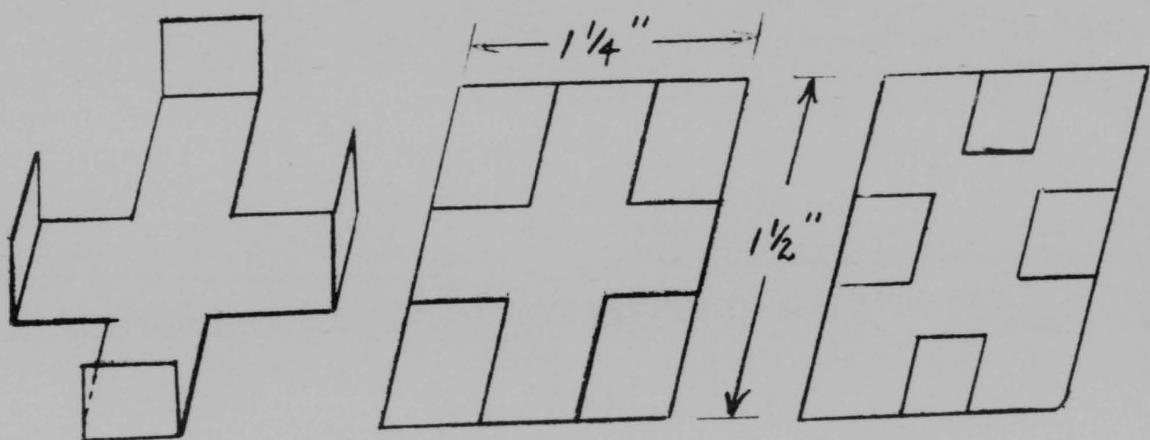
FILM BADGE

CHART 19-2



LEAD FOIL CROSS

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FILM BADGE WRAPPED IN PAPER

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TRAINING OUTLINE NO: 20

LECTURE: Monitoring Techniques.

TIME: One (1) hour.

PLACE: Classroom.

INSTRUCTORS' REFERENCES: Chapter 13, Chemical School Memo 393 (1 July 1949) (500) (WSW); Chapter 16, "AFRTC Manual 52-355-1", Dept of the Air Force, May 1949.

STUDENTS' REFERENCES: None.

TRAINING AIDS REQUIRED: Charts appended hereto.

1. Monitoring is defined as a continued check of the surroundings of an individual or unit in order to detect the presence of radioactivity. This definition is not broad enough, however, to cover all the phases of monitoring. These phases include determination of the type and intensity of radioactive contamination existing at any point, evaluation of the personnel hazards resulting therefrom and supervision of personnel entering contaminated areas.

2. In many respects monitoring can be compared to reconnaissance work. We must be looking for something specific, we must have the proper equipment, we must be able to immediately evaluate what we find and determine the course of tactical action to be taken. The long range effect or strategic results of radioactive contamination are the concern of Radiological Defense Engineers.

3. The reasons for monitoring are because of some overt act of war and sabotage by a foreign nation. These acts may be the explosion of an atomic bomb or some less obvious method such as radioactive dusts dropped during a conventional bombing attack, and acts of sabotage by foreign agents. In time of war, any area within 50 miles of such an attack should be considered suspect until proven otherwise by complete monitoring of all such areas. Therefore, preliminary plans for systematic monitoring of all USAF installations should be on hand and automatic warning devices be operational at all times.

4. The problem is threefold:

a. To determine the intensity of contamination present in critical areas and/or materiel.

b. To determine the general extent and degree of contamination existing in general areas.

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c. To prevent personnel entering contaminated areas from overexposing themselves through either ignorance, carelessness, or misguided enthusiasm for their mission. This does not mean that certain people on missions of vital importance should be denied access to contaminated areas.

5. The successful accomplishment of these tasks demands intelligent application of the material presented in previous lectures, tact, and occasionally, downright stubbornness.

6. Monitoring, to be successful and effective, should be carried out by teams. While a general rule cannot be drawn, each team should consist of at least two men. These men should be equipped with: Geiger and ion chamber instruments film badges, pocket dosimeters, gas masks, work clothing and a map or sketch on which to record data. They should, prior to making a survey, lay out a rough survey plan of the area and/or materiel to be covered in order that no time is lost while in the radioactive area. This plan should be based on the mission of the unit to which they belong. In general, preliminary monitoring is for the purpose of determining how soon an area can be reentered and how soon certain undamaged equipment in that area can be utilized. The first survey is normally a rapid one to gain information in the shortest possible time. In some cases, however, damage control and evacuation of wounded will be the primary aim.

7. To determine how soon areas may be safely reentered or equipment reused depends on the tolerance dose of radiation which personnel are allowed. We will assume 0.1 R/Day. Hasty initial surveys are limited to critical and essential areas or material necessary for use as soon as possible. Therefore, the monitors go to these points as rapidly as possible and obtain specific readings. General contamination is measured only as an approximation. The following procedure is outlined as typical:

a. As the suspected area is approached the Geiger counter is placed in operation with the beta window open. Pocket dosimeters are checked to insure that they read zero. Boots, gloves and clothing are checked for adjustment.

b. As the count picks up on the Geiger counter the team leader watches the meter closely and begins to estimate where dangerous radiation will begin. A rough estimate of the ratio of beta to gamma should be obtained. If the ratio of beta to gamma is high it generally indicates that:

(1) Alpha emitters are probably present as a definite hazard.

(2) Overall intensity will probably decay fairly rapidly.

c. When the count indicates 4-5 mr/hour (0.1 R/Day) this position should be marked on the map and some sort of ground marker put up.

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d. The monitors should proceed at a fast steady walk toward the desired objectives. An overall evaluation of the general contamination should be made rather than many spot readings. When the 12-15 mr/hr (0.3 R/Day) position is reached, this point should likewise be recorded on the map and marked on the ground since, up to here, personnel may remain for up to eight hours. At this point it is well to close the beta window and proceed with the survey, based only on gamma radiation.

e. When the 20 mr/hr position is reached it is necessary to change to an ion chamber instrument. Beyond this point the intensity will tend to increase at a more rapid rate if the monitor is proceeding toward the center of contamination. If at any point the readings start to decrease slowly but definitely it is an indication that the center of contamination has either been passed or does not lie in the direction of progress. A sudden sharp decrease in intensity generally indicates a small uncontaminated spot in the midst of a large contaminated area.

(INSTRUCTOR - REPRODUCE CHART 20-1 AND USE IT TO ILLUSTRATE THE ABOVE POINTS)

f. Above intensities of 100 mr/hr (2.4 R/Day) each monitor should check his pocket dosimeter every five minutes in order to determine how rapidly he is approaching his tolerance dose. Sufficient reserve should be maintained to allow leaving the area.

g. Within the limits of allowable dosage all critical points should be monitored and their intensity recorded. Monitors then leave the area as rapidly as possible. If buildings, rubble-covered holes or other confined spaces must be entered, gas masks may be needed for protection against the alpha hazards.

h. After leaving the contaminated area, monitors return to a central control point and report. Following this they turn in film badges and dosimeters, check themselves for contamination, bathe and, if possible, change into clean clothes.

i. Based on the findings of this survey, certain areas and/or material is either cleared for unrestricted use, cleared for use within certain working times or denied for access by personnel. When cleared for use for specified working times a monitor should accompany all working parties to enforce safety precautions.

8. If the object of an initial survey is damage control or evacuation of wounded, the monitor should accompany the working party as it progresses toward its objective.

9. As more time becomes available detailed surveys are made. These surveys are to determine the extent of and degree of contamination existing in contaminated areas. The procedure is similar to that used for hasty

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surveys except that all contaminated areas are located and their intensities determined. This information is plotted on a master chart in the form of isodose lines. Isodose lines are lines connecting points of identical radiation intensity. Thus any area outside a 0.1 R/Day isodose line would have an intensity of less than 0.1 R/Day and be safe for unrestricted use. As decay and/or decontamination progresses, remonitoring is accomplished and the chart altered accordingly. The decay equation $It^n = K$ is used to predict future decay.

10. Finally monitoring is reduced to a routine basis where the main task is monitoring of personnel working parties and supervision of working parties to see that time limits are not exceeded.

11. Air monitoring is the reconnaissance of air, land and water areas by airborne personnel for the purpose of detecting and avoiding, or of detecting, measuring and reporting the presence of radioactivity. The two general types of air monitoring work performed are:

a. Evasive monitoring which is an approach to the fringes of a contaminated area with the objective of locating these boundaries. Care is taken to avoid entering these areas and, based on data obtained, other aircraft can avoid contamination by passing around the area.

b. Survey monitoring is the type wherein survey aircraft enter contaminated areas to determine the location, extent and intensity of these areas.

12. Typical airborne monitors are equipped with the same instruments that are common to ground monitor personnel. Instrument calibration and operating skill are very important in air monitoring due to the time element. Typical procedure for air monitoring would be somewhat as follows:

a. Pilot and monitor would plan mission prior to take-off.

b. Monitor would brief crew on radiological safety procedures prior to take-off.

c. On evasive monitoring missions, continuous "in-flight" monitoring would be accomplished from time of take-off. The position location of each contact with contamination would be determined by the navigator and this information recorded. If time were important these data would be radioed back to a control center. The monitor would keep the pilot informed of the general radiological situation over the inter-communications system and advise when evasive action became necessary.

d. On survey missions this same general procedure would be followed. The monitor would notify the pilot when to proceed to additional areas or altitudes.

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e. Upon completion of the mission the monitor would monitor all flight personnel and the aircraft for contamination. Appropriate action would be taken if contamination were found.

MONITORING TECHNIQUES

13. Monitoring techniques are purely arbitrary rules which have been evolved to guide personnel in making surveys. They are based on practical experience obtained during past atomic energy tests, however, and should not be deviated from by non-technical personnel. It is assumed that each student is now fairly proficient in the operation of radiation detection instruments.

a. General.

(1) Care must be taken in monitoring to see that instruments do not become contaminated due to touching contaminated surfaces. Contaminated instruments give false readings and cannot be satisfactorily decontaminated. To prevent instrument contamination, due to accidents, a cellophane instrument cover should always be used.

(2) Accurate records should be kept of instrument battery life in order that replacement may be properly effected. Exhausted batteries result in erroneous readings.

(3) An instrument should be handled by only one man if possible. If not, a minimum of personnel should be allowed to handle instruments.

(4) Any malfunctioning or hard knocks on instruments should be reported.

(5) All readings should be taken at a uniform distance from the object being monitored. A one inch variation when using an instrument at close intervals may cause a large variation in observed intensities.

(6) Provision must be made to monitor and decontaminate all personnel working in contaminated area.

(7) Smoking, drinking, eating and gum chewing are specifically prohibited in contaminated areas.

b. Area Monitoring.

(1) Readings should be taken at belt height. While this

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reading is considerably lower than the actual intensity on the ground it is a fair indication of the average radiation intensity to which an individual's body is subjected. Also variations in height of the instrument from the ground due to monitor's height is minimized.

(2) Generally gamma readings only are obtained.

(3) Only rough average intensities over large areas are obtained. The monitor should average the general readings in his mind and arrive at an overall figure. Local "hot spots", however, should be traced down and marked.

(4) The intensity of areas which cannot be entered may be estimated through use of the $I = \frac{CM}{D^2}$ relationship. For example, if in circling a very hot spot the monitor obtains a reading of 0.1 R/Day around the edge of a rough circle 9 feet in radius, he may assume an intensity of 8-10 R/Day near the center of the circle. This is only a rough approximation and must be considered as such.

(5) Special attention must be given to wood, concrete, bituminous and other porous surfaces since these tend to absorb and retain contamination.

c. Equipment Monitoring

(1) Readings should be taken one inch from the surface. This is facilitated by mounting an improvised guage on the instrument.

(2) Items such as rope, canvas, rough or rusted surfaces, greasy and oily surfaces, bituminous coverings, pumps, drains, wood, air intakes and water systems should be closely checked.

(3) Care must be exercised to obtain readings which represent only contamination existing on equipment. In some cases localized "hot spots" on the ground may give distorted values to readings obtained on equipment in that area.

d. Personnel Monitoring.

(1) All readings should be taken as close to the body surface as possible without actual contact.

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(2) Personnel returning from a contaminated area should first remove all expendable protective devices such as boots and turn in equipment. Then, one man at a time, each individual should be taken to an area with low background count and monitored with his clothing on. Any reading over 0.2 mr/hr, beta plus gamma, indicates contamination and decontamination measures should be accomplished.

e. Airborne Monitoring.

(1) Calibration of instruments is necessary at the altitude which they are to be used.

(2) Only gamma readings have any significance.

(3) Coordination is necessary between the monitor and navigator to determine position locations.

(4) Aircraft oxygen systems should be used in contaminated areas with the regulator in the 100% position. Cabin heater systems should be turned off.

(5) Aircraft should not enter areas where the intensity is high, since, due to instrument lag and the inability of aircraft to instantly reverse direction, highly dangerous areas may be entered almost without warning. In addition high intensity areas will contaminate an aircraft rapidly.

(6) Aircraft must be monitored after landing. Most likely sources of contamination are air intakes, turbo-superchargers, engines and leading wing surfaces.

(7) Monitors should be located in forward nose compartments.

Are there any questions?

INSTRUCTOR'S QUESTIONS:

1. What is monitoring?

2. What are isodose lines?

3. What is the significance of the 4-5mr/hr isodose line? The 12-15 mr/hr isodose line?

4. What must a survey team do when they reach a 20 mr/hr intensity?

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5. What is the significance of a high beta to gamma radiation ratio?

6. How can future radioactive decay be estimated?

7. What are two types of air monitoring?

8. What are three things that are always prohibited in contaminated areas?

9. What radiation intensity indicates personnel contamination? Is the gamma or gamma plus beta?

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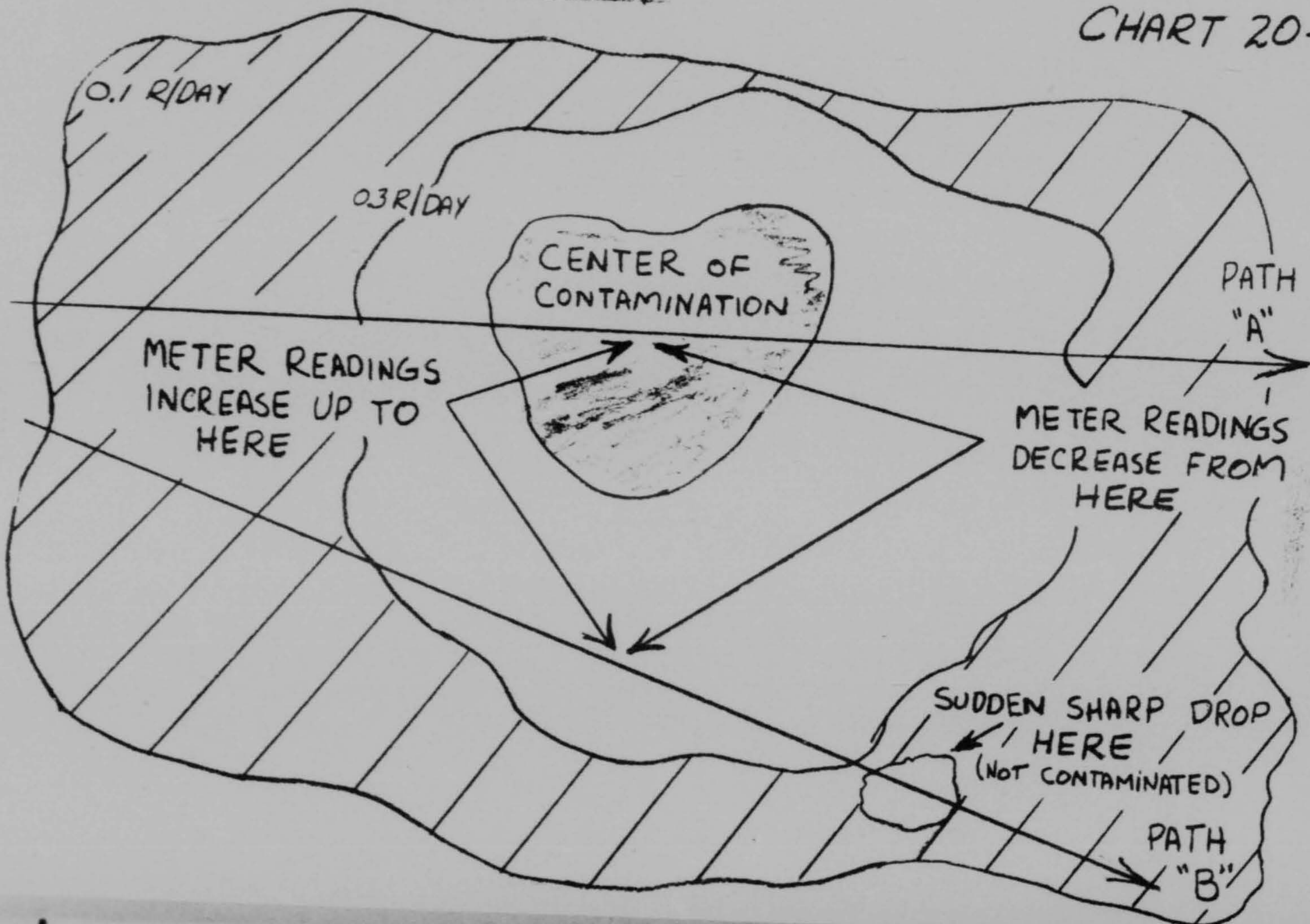
CONTAMINATED AREA

CHART 20-1



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TRAINING OUTLINE NO:	21
LECTURE:	Individual and Collective Protection.
TIME:	One (1) hour.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	All previous references.
STUDENTS' REFERENCES:	None.
TRAINING AIDS REQUIRED:	Charts appended hereto.

1. This hour is devoted to individual and collective protection against the atom bomb and associated radiological hazards.

2. These hazards are illustrated by Charts 21-1, 21-2. From the original neutron striking the fissionable material, and the resulting explosion, in addition to immense blast, there are fission products, most of them radioactive, prompt radiation consisting of the neutron flux and gamma rays, heat of sunlike intensity, blinding glare, and one or two other phenomena.

3. What can the individual do - acting as an individual? At the sounding of the alert, take the best shelter available. The few people who were in deep earth tunnel shelters at Hiroshima and Nagasaki were not harmed when the bomb was detonated. Even a foxhole would be enough, providing the bomb was not detonated directly or nearly overhead. If it is off to one side, the penetrating radiation has to go through several feet of earth to reach you.

(INSTRUCTOR - REPRODUCE CHART 21-3)

If an earth covered or concrete air raid shelter is available, use it.

4. One thing <u>not</u> to do. DO NOT stay out of the shelter to watch the flak bursts as the enemy planes come in. DON'T look up during any raid. Wear your helmet. Cover your face and keep it turned toward the ground.

5. It has never been announced, as to just what thickness of earth, brick, concrete or other material will provide protection from prompt radiation. Neutrons, however, are very penetrating, and a minimum of four feet of reinforced concrete should be required in shelters.

6. Shelter doors should be closed, or if in a foxhole, a cover should be used. People in deep tunnel shelters in the Hiroshima blast

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were slightly burned in some cases where the heat wave struck the open shelter entrance directly.

7. Try to select a shelter that won't come down or burn if it does collapse. It is known than many of the thousands who died at Hiroshima and Nagasaki were trapped in the burning debris of collapsed houses. Never take shelter under a vehicle except as a very last resort.

8. If caught in the open a mile or so away from the blast, the chances of survival are better if white or light colored clothing is worn. It reflects the heat, and thus protects the body, whereas dark clothing absorbs the heat radiation, and the body beneath is burned badly.

9. Assuming that you are uninjured after the bomb has burst, you, as monitors, will have a very definite job, and would carry out the duties assigned under the unit defense plan. Other personnel will also have assigned duties such as fire fighting, or rescue work. Fires will be burning all around the place, both spontaneous fires caused by the heat of the bomb burst, and secondary fires caused by short circuits, overturned stoves, burst gasoline tanks and other sources.

10. It would be best to put on a gas mask until a check shows whether the area is free of contamination or not. And most important, DON'T eat, drink, or smoke in a possibly contaminated area until the degree of contamination or its absence is established, then abide by instructions from higher headquarters.

11. If you suspect or know that your person or clothing is contaminated, get to a personnel decontamination station immediately. If you were within a mile of the blast, and especially if you feel nauseated or have been wounded, get medical attention promptly, if possible.

12. If you are away from your unit and away from the instruments required for detecting and measuring dangerous radioactivity, always keep in mind the possibility of fall-out even from an atomic explosion, many miles away. Stay inside, and avoid food and water where any possibility of contamination exists, until authorities anounce the district as clear.

13. On the question of collective protection, there is one fact which should be understood before any discussion is undertaken. We may be reasonably sure that no atomic bombs will be used on purely tactical targets. They cost too much, and it is fairly certain that no nation will ever have large quantities of atomic bombs. It is considered that the bomb would be used only on a tactical objective where its use would be decisive to the outcome of a war. Therefore, a bomb probably would not be used on an airbase, or against troops in the field.

14. More likely is the enemy use of large capacity bombs, gliders,

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or guided missiles loaded with radioactive dusts. These are relatively cheap, and a comparatively small amount can force evacuation of an area.

15. Considering the above possibilities, it is highly probable that USAF policy will be against the construction of elaborate deep shelters, which are very expensive, and that any construction effort will be directed toward simpler surface or semi-sub surface shelters, capable of holding all the personnel of a given installation. Such shelters may be gas proofed and equipped with collective protectors, may have non-combustible tight sealing doors, include sanitary facilities, may have storage space for food and water, and, since many would be area defense centers, may have telephone and/or radio communication with other shelters in the same vicinity. Whether they are made of brick or concrete, such shelters should be banked and covered with earth to provide additional shielding for the occupants.

16. Dispersion of personnel and equipment over a wide area is an obvious and effective method of collective protection, and dispersion should be utilized to the utmost at all times, and practiced in peacetime so that dispersion becomes an established habit for times of war. It must apply to key personnel, medical facilities, vehicles, planes, ammunition, fuels - to all the components which go to make up a unit able to perform its mission.

17. Most of the considerations applicable to collective protection should be covered by unit and base defense plans. These will be discussed at a later period.

18. Such defense plans must be simple, practical and kept up to date, for there will be little time for improvisation in the event of an emergency. Personnel concerned must know their jobs beforehand and set to work immediately after the attack. Such plans must include a SOP for all individuals, including the unit radiological defense group.

19. Other facilities required for collective protection include personnel decontamination centers. These are emergency bathing facilities which have a clean and dirty side as in personnel gas decontamination centers. Normally, first aid personnel should be stationed here, and also a monitor to check personnel going through.

20. Instrument storage facilities for delicate detection instruments will be required. Space may be set aside in shelters for this purpose, and here again, the principle of dispersion used, since all instruments should never be concentrated in one spot.

21. A Damage Control Organization of fire fighters, rescue teams, and first aid personnel will be essential. This should be organized on a unit basis, so that teams from an unaffected area can go to heavily hit areas. Equipment for these units should be dispersed.

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22. Every installation should have a designated Evacuation Area or Assembly Point to which personnel could proceed in the event that area evacuation is required. Such areas can be stocked with emergency supplies of food and water and medical facilities. An evacuation area should be chosen after consideration is given to the probable fall-out (prevailing winds being known) from an atom bomb on any local potential target.

23. Prevention of panic will be a major factor in collective protection. This can be accomplished only by thorough training of all personnel in all echelons and by an effective working organization for defense.

24. It is unlikely that Air Force units will have any direct concern with civilian defense, but the use of Air Force personnel in disaster control to assist the Civil Defense authorities is always possible. Should that occur, personnel with specialized training as monitors will have an important function.

Are there any questions?

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CHART 21-1

ATOMIC EXPLOSION

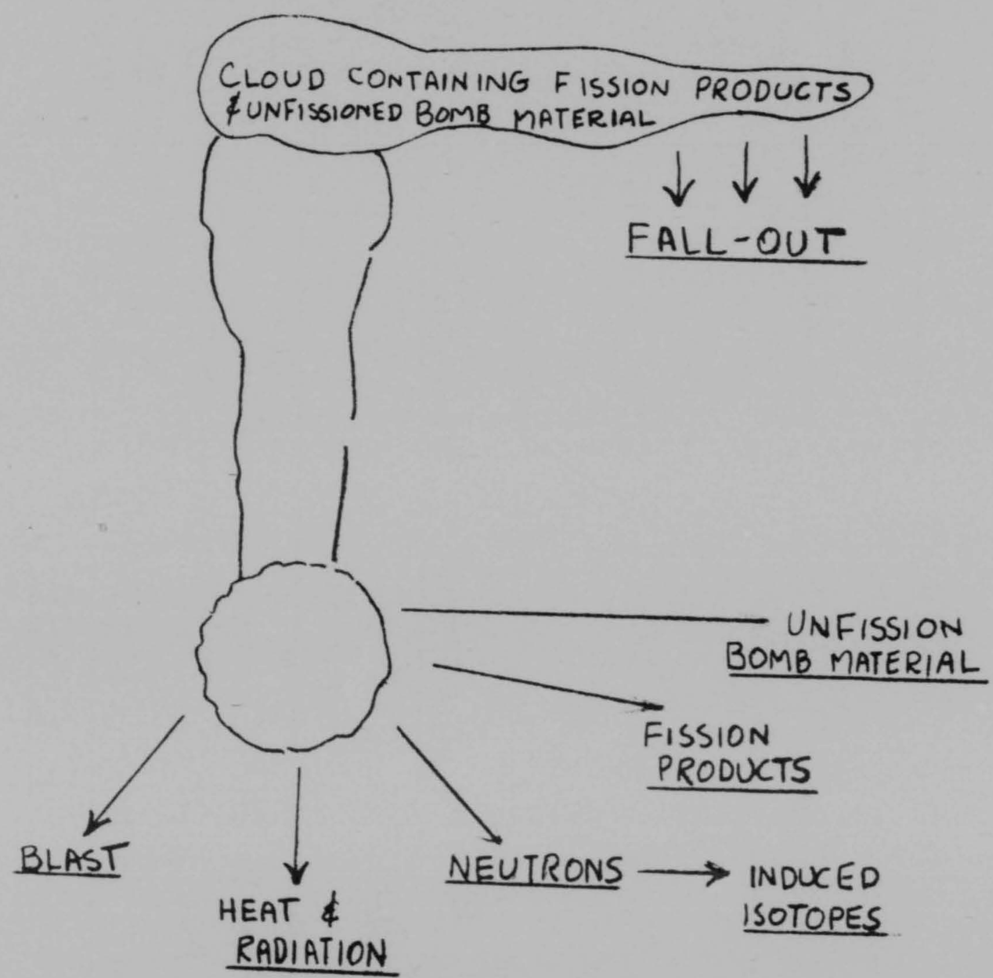
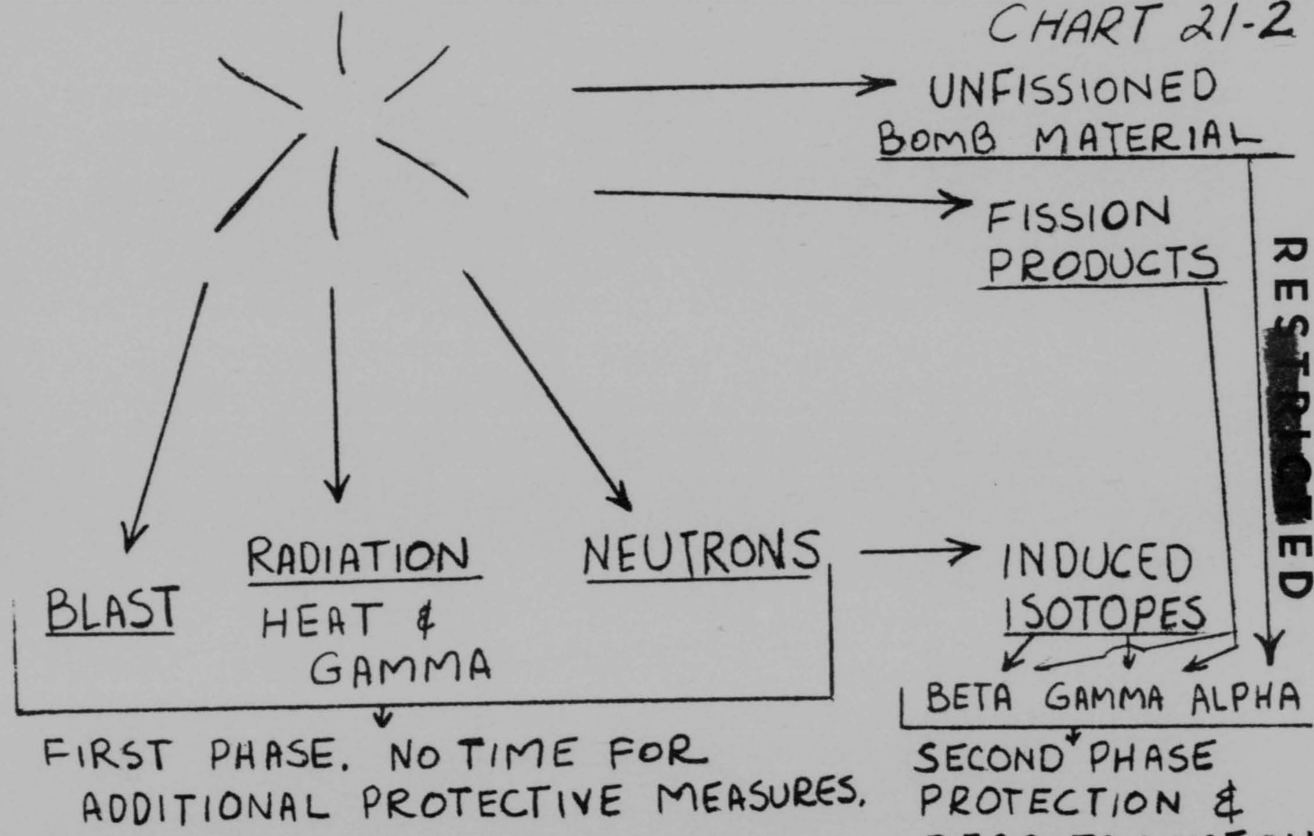


CHART 21-2



ATOMIC BOMB HAZARDS - TIME PHASES

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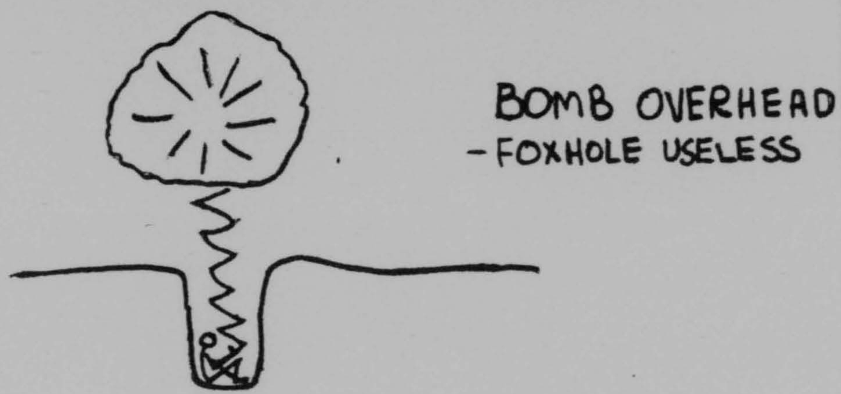
CHART 21-3

INDIVIDUAL PROTECTION



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TRAINING OUTLINE NO: 22

LECTURE: Decontamination Procedures.

TIME: One (1) hour.

PLACE: Classroom.

INSTRUCTORS' REFERENCES: Chemical School Memo 202, 22 June 1948; Chapter 10, Chemical School Memo 393 (1 July 49) (500) (WSW); Page 14-5 and 14-6, "AFRTC Manual 52-355-1", Dept of the Air Force, May 1949.

STUDENTS' REFERENCES: None.

TRAINING AIDS REQUIRED: Charts appended hereto.

1. Decontamination is the removal of radioactive contamination from personnel, materiel and areas.

2. Inasmuch as there is no practical way to destroy radioactivity, decontamination must be accomplished by physical removal of the radioactive material. This material is in the form of sub-microscopic particles scattered over large areas some of which is firmly imbedded in surface areas. For that reason, and because by decontamination we merely transfer the radioactivity to another place, it is normal procedure to let radioactive decay take care of decontamination. With one exception, therefore, decontamination is normally limited to a few critical areas and/or items of materiel. That one exception is personnel decontamination.

3. While it is not the scope of this course to teach tactical doctrines on decontamination, a few general principles should be outlined. This is felt to be of particular importance since commanders, staff officers and operating agencies, almost without exception, often misunderstand what it is possible to accomplish with decontamination measures. The points which should be understood are:

a. Decontamination, except for personnel decontamination, should never be attempted except for critical items of equipment and very small areas. This is because decontamination is a process which consumes large amounts of supplies and man-hours of work. In almost every case dangerously contaminated equipment should be allowed to age and contaminated areas abandoned.

b. Decontamination is a slow process which in many cases, depending on the type of material and conditions of contamination, is only partially successful.

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c. It is very difficult to evaluate the success of decontamination measures since such factors as natural decay and weathering often a are actually responsible for supposed decontamination.

d. Personnel decontamination, by contrast, is simple and a relatively minor but important problem.

4. The bulk of the information in the remainder of this lecture will be devoted to personnel decontamination techniques since this is well within the province of a monitor. Other types of decontamination, while discussed briefly, should not be undertaken in the absence of a qualified Radiological Defense Officer.

PERSONNEL DECONTAMINATION

5. Personnel working in a contaminated area or persons who may be in an area over which contamination is spread will require decontamination. Because both their clothing and parts of their bodies may pick up radioactive particles, it is necessary to monitor these personnel and establish decontamination centers.

6. All clothing is subject to the hazards of contamination but gloves and shoes are usually the more heavily contaminated. Canvas booties, if available and worn, will protect shoes completely, and can be discarded after use. When shoes are not protected, however, they will pick up dangerous amounts of contamination on the top, edge and bottom of the soles. Cord-rubber and rubber soles are much worse in this respect than leather soles. Canvas gloves are highly desirable to protect the hands against contamination but are very clumsy if precise work must be done. Despite some opinions to the contrary, it has been proven that monitors can operate instruments quite satisfactorily while wearing gloves.

7. The fact that work clothing has been used once in a radioactive area does not mean that it should be promptly discarded even if slightly contaminated. On the contrary, as long as clothing reads below 3 mr/hr, beta plus gamma, it may be worn for work periods of 4 to 6 hours quite safely.

8. On the body, special attention should be given to the hair, face and hands as probable locations of contamination. If gloves are not worn, it will be found that grime beneath the fingernails is always contaminated. The entire body must be checked, however, after all clothing is removed.

9. A diagrammatic sketch of a personnel decontamination center is shown on the following chart;

(INSTRUCTOR - REPRODUCE CHART 22-1)

Emphasis must be placed on the fact that almost any type of facility

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which has a source of running water can be used for decontamination. The cardinal rule is to keep contaminated personnel and equipment out of "clean" areas. Procedure is as follows:

a. Personnel assemble in an area and turn in equipment. Gloves and booties are then discarded.

b. One man at a time, each individual is monitored with his clothing on. Remainder of personnel should remain 30-40 feet away to keep a low background count.

c. Readings should be taken as close to the clothing as possible, and should be beta plus gamma readings.

d. Any clothing reading higher than 3.0 mr/hr, beta plus gamma, should be discarded. Only those articles of clothing so reading should be discarded. Replacement items should be issued at time of discard.

e. Clothing reading 3.0 mr/hr, beta plus gamma, or less should be stowed away for future use.

f. One man at a time, each individual should then be monitored without any clothing on. Any appreciable increase in background count shows some degree of contamination and, unless shortage of water is a factor, the man should be decontaminated. If water shortage is a factor, only men reading over 0.2 mr/hr, beta plus gamma, need be decontaminated.

g. Decontamination is accomplished by scrubbing down with soap, water and a GI brush. Several applications may be necessary.

h. Men are then checked by a monitor and, if clean, are given a towel. If necessary, men are sent back to the showers until free of radioactivity.

i. Men are then cleared to dress and are released.

10. Certain modifications may be necessary in this procedure with respect to issuing clean or replacement clothing. There is little objection to how this is done as long as contaminated personnel do not handle dress clothing. By dress clothing is meant clothes which will be worn after release from a monitor's supervision. It should not be confused with clean or slightly contaminated work clothing which will be worn under a monitor's supervision only - there is little objection to contaminated personnel handling this work clothing.

11. The major requirements for operating personnel decontamination

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centers are running water, soap, brushes, towels, a supply of clothing and a place for work parties to stow or hang two sets of clothes. These two sets of clothing as pointed out above, are dress clothing and work clothing. In connection with work clothing, it is well to point out that personnel working in radioactive areas should be furnished a minimum of clothing. A cap, a shirt, a pair of trousers, a piece of heavy twine for a belt, and a pair of shoes is all that is needed. To this should be added a pair of canvas gloves and a pair of canvas booties as expendable items for each mission. Underwear and socks are not normally necessary and complicate supply problems. In winter weather, however, they might be required. Towels are not a problem if care is used to insure that they do not become contaminated. Clothing which has become contaminated should not be arbitrarily destroyed but stored so that radioactive decay may render it useable again.

12. Personnel requirements for operation of a decontamination center will range from 4 to 6 persons, if men are to be processed rapidly. At least three monitors are necessary to handle a continuous flow of personnel.

13. Finally,-it is necessary to exercise strict supervision over all personnel entering radioactive areas to insure that they are properly decontaminated before release. It is a proven fact that personnel get careless after working on a dangerous job for some time. One of the biggest jobs will be to combat such carelessness.

<u>MATERIEL DECONTAMINATION</u>

14. Materiel decontamination should be carried out in an area which is uninhabited and where contamination of the ground by run-off of decontaminating solutions is not objectionable. Care must be taken that:

a. Men work upwind of the object being decontaminated.

b. Washing down must begin at the highest levels and work down.

c. All portions of the object being decontaminated are equally washed down.

15. Specific procedures for decontamination are as follows:

a. <u>Aircraft</u>: Aircraft may be decontaminated by spraying with a mixture of kerosene and "gunk" (Compound, cleaning, aircraft, Specification No. 20015). This mixture can be sprayed on by use of a 400 gallon power driven decontaminating apparatus (M3A2 or M4) which delivers a working pressure of about 400 lbs., per sq., in. An additional decontamination apparatus, utilizing water, or a steam cleaner should be used to wash down the gunk mixture. Suitable fire precautions will be taken.

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b. Metal Surfaces (Corrosion not permissible): Use the gunk solution outlined above.

c. Metal Surfaces (Corrosion permissible):

(1) Swab surface with a weak acid solution and follow by washing down with a stream of high pressure water.

(2) On painted surfaces, it is very effective to remove the paint. This may be done by use of a solution consisting of:

5 lbs lye (Na OH)
5 lbs boiler compound
1 lb cornstarch
10 gallons water

which is allowed to remain on the paint for two hours before removal with a high pressure water stream.

d. Wood Surfaces: Decontamination of wooden surfaces is impractical beyond a hosing down with water.

e. Canvas and Fabrics: Washing with soap and water is the most that can be done. Except for clothing, this type of material should be destroyed.

AREA DECONTAMINATION

16. There are three possible methods whereby areas may be decontaminated, none of which are satisfactory. They are:

a. Wash down with high pressure hoses and transfer contamination to another area.

b. Cover the area with a layer of uncontaminated material, (i.e., dirt, duckboards, steel matting, etc.)

c. Remove a layer of the topsoil with power equipment. Some disposal area must be utilized.

Are there any questions?

INSTRUCTOR'S QUESTIONS

1. What are booties? Why should they be used, if available?

2. Below what intensity can contaminated clothing be used for work periods of 4-6 hours? Is this gamma only or gamma plus beta intensity?

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3. What parts of the human body are more likely to pick up contamination in contaminated areas?

4. What is a cardinal rule to follow in the operation of a personnel decontamination center?

5. If water is scarce, what is the maximum intensity of radioactive body contamination that a person may have without requiring decontamination? Is this gamma only or gamma plus beta intensity?

6. How are personnel decontaminated?

7. What decontaminating agent may be used for cleaning aircraft? What type of decontaimnating apparatus is best suited to this job? What precautions must be taken?

8. Can wooden surfaces be decontaminated? How?

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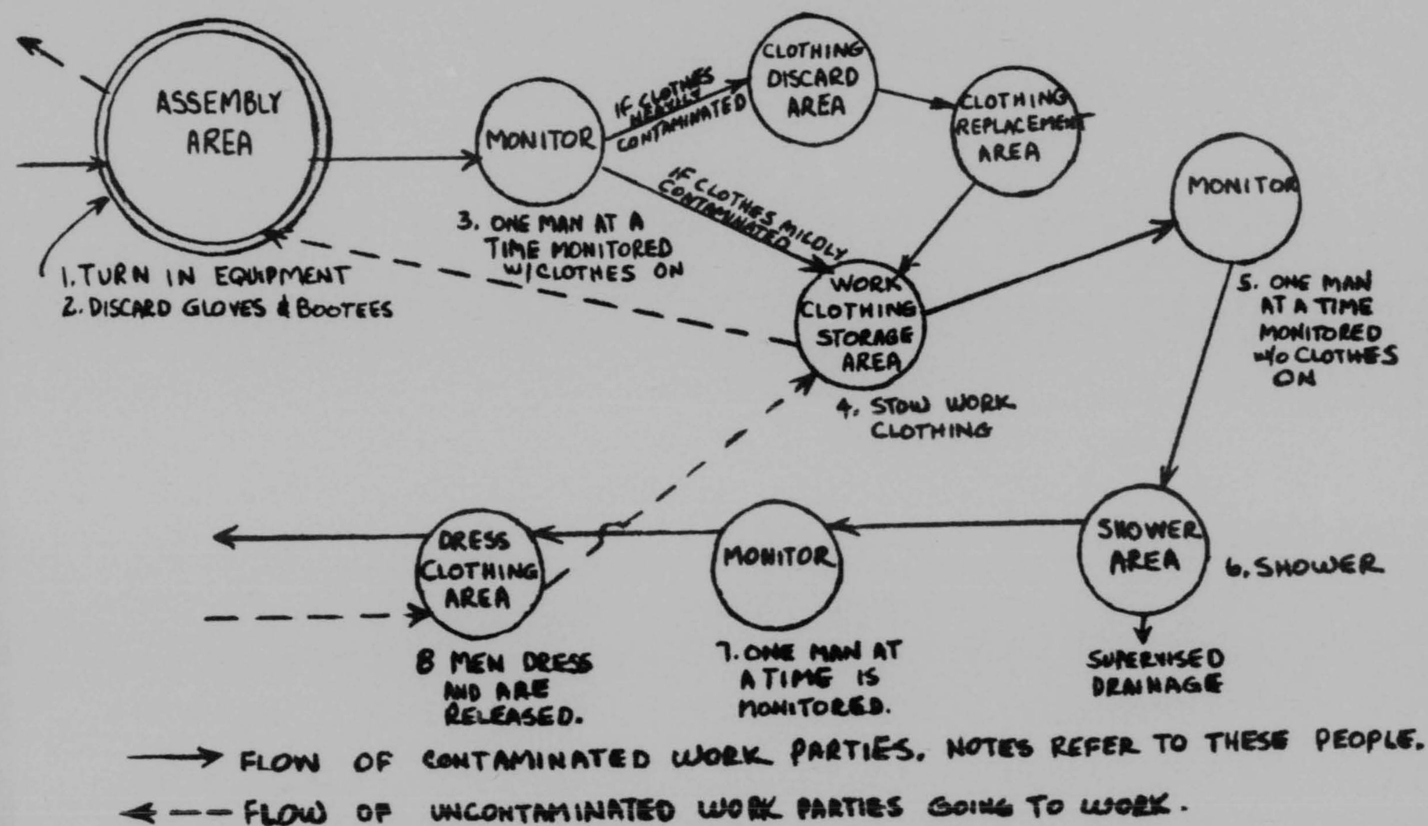
PERSONNEL DECONTAMINATION CENTER CHART 22-1



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TRAINING OUTLINE NO: 23

CLASS EXERCISE: Monitoring Field Problem - 263A Survey Meter.

TIME: Two hundred (200) minutes.

PLACE: Outdoor Area.

INSTRUCTORS' REFERENCES: None. (See Footnote*)

STUDENTS' REFERENCES: Notes from previous periods.

TRAINING AIDS REQUIRED: 263A Survey Meters. Radium Source, pocket dosimeters, dosimeter charge box, film badges, data sheets, maps or sketches, clipboards.

1. Objectives:

a. To have students check 263A meters and pocket dosimeters and prepare survey plans.

b. To have students survey an area and determine the general overall intensity thereof.

c. To have students determine the location and intensity of hot spots within a contaminated area.

d. To have students determine and roughly plot on a map the location of 0.1 R/Day and 0.3 R/Day isodose lines in a contaminated area.

e. To have each student determine his dosage for the period of exposure.

*Development of this field problem is left to the instructor since local circumstances such as size and quantities of sources available, size and types of areas available, and number of instruments available will vary. The objectives to be obtained from this field exercise are given in the subject outline below. As a result of the survey, each student or team should prepare a short report to accompany the sketch and these turned in for grading. Too much emphasis cannot be placed on the instructor "dry running" this exercise before actual presentation to a class.

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2. General Procedure:

a. Students will draw 263A meters and check these meters; draw pocket dosimeters and charge these dosimeters; prepare data sheets; and, based on instructor's briefing, make a rough survey plan. This survey should be made by teams, each team consisting of 2-3 students.

b. Teams should proceed to the contaminated area and, using hasty circling tactics determine the location of the 0.1 R/Day and 0.3 R/Day isodose lines. The location of these lines should be sketched on a map of the area.

c. Teams should then work in toward the center of the areas located in (b) above and determine the location and intensity of "hot spots" (i.e. sources). The location of these "hot spots" should be plotted on the survey map.

d. Upon completion of the survey, teams should determine their dosage from pocket dosimeters, turn in instruments and prepare a report on the general overall condition of the contaminated area. The survey map should accompany this report and be graded for legibility and accuracy.

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TRAINING OUTLINE NO:	24
CLASS EXERCISE:	Monitoring Field Problem - 247A Survey Meter.
TIME:	Two hundred (200) minutes.
PLACE:	Outdoor Area.
INSTRUCTORS' REFERENCES:	None.
STUDENTS' REFERENCES:	Notes from previous periods.
TRAINING AIDS REQUIRED:	247A Survey Meters, Radium Source, pocket dosimeters, dosimeter charge box, film badges, data sheets, maps or sketches, clip-boards.

This field exercise is comparable in scope to Training Outline No 23 except that the 247A meter will be unsed for survey purposes. Multiplication factors may be arbitrarily assigned for the radiation intensities present. If this is done, however, care should be taken that the isodose lines, assigned to be determined, are of correspondingly higher values. For example: If a multiplication factor of 10 is used the students might be required to determine the location of the 0.3 R/Day (0.1R in 8 hours) and the 0.6 R/Day (0.1R in 4 hours) isodose lines.

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TRAINING OUTLINE NO:	25
LECTURE:	Radiological Defense Organization.
TIME:	Two (2) hours.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	Pertinent AF Directives. All previous material. Chapter 15 and 16, "AFRTC Manual 52-355-1", Dept of the Air Force, May 1949; Chapter 7 and 8, Chemical School Memo 202, 22 June 1948; Medical Aspects of Nuclear Energy AFSWP, NME 1949.
STUDENTS' REFERENCES:	All previous material.
TRAINING AIDS REQUIRED:	Copies of AF Regulation 20-28, 3 May 1948 and copies of Air Base Radiological Defense Plans included with these notes. Copies to be issued to all students for retention. Blackboard map of Air Base.

Note to Instructor:

Policy decisions are still lacking on many of the matters discussed in this lecture. For that reason, no material should be presented as representing USAF policy unless covered now by existing directives such as AF Regulation 20-28.

1. The entire subject of radiological defense organization has not yet crystallized, and a firm policy is not as yet available. It is believed that this condition will be corrected in the very near future, however, and that organization will proceed on the following principles.

2. The fundamental USAF policy directive is AF Regulation 20-28, 3 May 1948, of which you all have copies.

3. In practice, responsibility is divided as follows:

a. The Atomic Energy Commission has general control over all phases of atomic energy and its applications, and over all specialized training in that field. Through its Military Liaison Committee, it works with the Armed

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Forces Special Weapons Project, and the Air Force. In Headquarters USAF there is an Assistant Deputy Chief of Staff, Operations for Atomic Energy, but actual training for defense is supervised by the Radiological Defense Branch in the Office of the Director of Armament, USAF, which oversees all matters pertaining to Radiological Defense in the Air Force. At a lower level, in Air Force Commands, the Command Armament Office is also the Radiological Defense Office. The same is true at Air Force and Wing level.

b. At Group and Squadron level, student of this course will assume radiological defense duties for units, in addition to chemical duties in most cases.

4. What special training is necessary in radiological defense work? There are several categories, and we will note them briefly.

a. There is a three year course given to selected officers from which they emerge as Radiological Defense Engineers. It is contemplated that these officers will be assigned to Command or possibly Air Force level.

b. The six weeks course qualifies an officer as a Radiological Defense Officer. Three schools are currently being conducted for this course at the following installations: Treasure Island at San Francisco, The Army Chemical Center, Maryland, and Keesler Air Force Base, Mississippi.

c. Additional courses are contemplated to qualify selected officers and airmen as survey officers and instrument maintenance specialists respectively. The training given here is considered as the basic course for survey officers and as an adequate course for the qualification of radiological monitors.

5. No formal organization has been set up for Wing Radiological defense, though several tentative suggestions have been made. An organization of the tentative type will be considered in discussing Radiological Defense plans.

6. The plan for the protection of an organization, or an installation, against atomic explosion or other form of radiological attack may take a variety of forms. It is probably not too important what form is used, as long as the plan is a workable one. However, the individual formulating the plan should have a definite form in mind and follow that form. Otherwise, it is almost certain that details which are important will be overlooked. Possibly the best answer here is that the same form should be followed as has been followed by the organization in the past in preparing its defense plans.

7. Once a decision has been made as to what form the plan will take, it must be decided what amount of detail will be included in the plan. No set rule applies here. A poorly trained and relatively inexperienced

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organization must have a plan which is more detailed than would be necessary for a well organized and trained organization. Too, the type and mission of a unit will have much to do with the type of plan and the detail with which duties and responsibilities are outlined.

8. The following check list is presented as a guide only. In some plans, all of the details mentioned need not be considered. In others, it may be necessary to include details not mentioned in the check list. However, it is believed that this list is complete enough to serve as a guide for relatively inexperienced personnel in writing up their first plans.

a. Responsibilities. Who is charged with directing radiological defense? What is his status with respect to the Commanding Officer? Other staff officers? Are all interested staff agencies coordinated in a single plan?

b. Organization. What base organizations will have Radiological Defense Officers? Which will have only monitors? Will they be enlisted or officer personnel? Will any civilians be utilized here?

c. Training. What special training is necessary? Do all personnel get the same training? Who is responsible for general indoctrination type of training? Who is responsible for special training and the development of special skills?

d. Warning System. Are any special warning systems needed? Who is responsible? Any special signal for evacuation of the installation?

e. Dispersion. To what degree? Materiel, personnel, or both? Are duplicate command posts necessary? Evacuation areas designated? Stocked?

f. Shelters. For all personnel? For any type of materiel? For medical and special equipment? What type will be constructed? Who will design? Are there any useful types of hasty field shelters?

g. Monitoring. Who directs and supervises? Who does the work? Who monitors materiel? Personnel? Areas? Will there be a fast survey made first and then a detailed survey? What types of instruments will monitor use? Should provision be made for continuous monitoring? Will monitoring be done to detect radioactive dusts, radioactive war gases, and isotopes which may

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be spread without an explosion? Who monitors food and water supplies? Do firefighters enter the area after an explosion without monitors? Who must make the decision as to whether firefighters and medical personnel enter a contaminated area? Will the monitor be delegated authority to say who goes in? Will monitoring priorities be necessary?

h. Communications. Is it necessary to set up any sort of special service to use after an explosion? Any restrictions on use of communications after an explosion? Who is to be responsible for special communications?

i. Supply. Who supplies and services the radiation detection instruments? The film badges? Who develops film badges? Who furnishes chemicals and special tools for decontamination work?

j. Fall-out Areas. Who will estimate and advise the commander as to area or areas which will be contaminated by fall-out particles? Should this estimate be made after an explosion, or should it be a continuing estimate so that the commander may be informed of the expected area of fall-out immediately after an explosion?

k. Plans for Civilians. Is it necessary to make any special plans for civilian employees? If so, who is responsible?

l. Personnel Decontamination. Where will personnel decontamination centers be established? Who is responsible? Who will operate? What special equipment will be necessary? Can existing bathing facilities be used, with or without alteration?

m. Materiel Decontamination. Who is to be responsible for decontaminating areas? Buildings and other installations? Equipment?

n. Special Instructions. Are any special instructions necessary for general and specialist personnel?

o. Medical. Are policies established on casualty procedure? What plans for evacuation and treatment of personnel? Allowable radiation dosage for monitors? Other individuals?

9. All the above points must at least be considered in writing an adequate defense plan.

10. The defense plan of a large air base, occupied as it is by many and various units having different functions, is bound to be complex. It is not likely that with your present status of training

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in radiological defense that you will ever be called upon to write such a plan - that is a job for a fully trained Radiological Defense Officer - but a summary will illustrate the many problems involved in such a plan.

NOTE TO INSTRUCTOR:

1. Read and explain attached plan with cover letter. It will be found helpful to draw a map of a representative large air base on blackboard to aid in explanation. It will be stated that this plan is tentative, and is not final USAF policy, but that it does offer one solution. There is, of course, no Composite Air Command, and students will be so informed.

2. The attached plan for "Defense of a Small Air Force Unit" will be read and explained to students. They will be told that such a plan will be within their scope of activitiy in their unit radiological defense.

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SAMPLE COPY

Headquarters
Air Composite Command
Pittsford Air Force Base
New York

7 April 1948

Subject: Radiological Defense of Air Composite Command Installations.

To: Commanding General, Twenty-second, Twenty-fourth, Twenty-seventh, and Twenty-ninth Air Forces.

1. The attached "Installation Radiological Defense Plan" is forwarded for information and guidance of commanding officers in all echelons of this Command.

2. Effective immediately, a radiological defense plan based upon this supplied model will be implemented and maintained for all Composite Air Command installations.

3. The atom bomb and associated radiological weapons represent new modes of warfare, many aspects of which are of necessity unfamiliar. In order that full advantage may be taken of known principles of radiological defense, and to insure desirable uniformaty of procedures throughout this Command, the provisions of the attached plan will be considered as representing Command policy, until further notice.

4. It is realized that certain installations notably Air Force Headquarters, detached organizations, and others present defense problems varying widely from that of an air base. Commanding Officers of such units will formulate suitable defense plans, stressing dispersion and the ability to continue operations under battle conditions. Such plans will be forwarded through channels to this Headquarters for approval, but meanwhile, will be made operative.

5. It is anticipated that qualified Radiological Defense Officers will be assigned to major organizations of this Command, down to and including Wings, in the near future; these officers will advise unit commanders in all matters pertaining to Radiological Defense.

BY COMMAND OF LIEUTENANT GENERAL O'SHEA:

ANNEX 1

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SAMPLE COPY

Headquarters
Air Composite Command
Pittsford Air Force Base
New York.

Installation Radiological Defense Plan

1. Introduction

a. The following plan provides for the defense of a typical Wing Base of this command against atomic bomb or associated radiological attack. It will be integrated with, and will extend existing plans against chemical and biological attack.

b. Radiological, biological, and chemical defense will be coordinated and supervised at all echelons by the Armament organization, but can only be successful with the full cooperation of all personnal and staff sections as required.

2. Responsibility and Organization

a. The Commanding Officer of the Wing is responsible for the defense of the base. He will be advised and assisted in the radiological defense of the base by the Radiological Defense Officer (RDO) who will coordinate all measures to be taken by the Radiological Defense Organization and associated specialists before, during, and after any attack in which radiological munitions may be involved.

b. The Radiological Defense Organization will consist of (See Chart A, attached):

(1) The RDO, in Wing Headquarters, and commissioned and enlisted assistants.

(2) Survey Officers (SO), one in each unit of the Wing. These are qualified monitors who have received required training in radiological defense. SO's are assisted by enlisted Radiological Monitors (RM) varying in numbers in each unit according to its function. Unit Gas personnel will be designated for this duty.

(3) Each unit of squadron size will maintain 20-man squads trained in decontamination, rescue, and fire fighting, to operate under the unit SO. These squads will function as Unit Damage Control Groups.

Inclosure 1 to Annex 1

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(4) A Photodosimetry Laboratory (Hospital).

(5) Instrument specialists in Maintenance Squadrons.

c. Each unit will be responsible for radiological defense measures in its own area under direction of the unit SO, and under general direction by the RDO. Chain of command will be observed in wing defense organization, thus the RDO under battle conditions will receive reports from and direct action of Group SO's, who will in turn receive reports from and direct Squadron SO's.

3. Defense Facilities

a. Shelters

(1) USAF policy does not allow heavy construction as would be required for elaborate bomb proof shelters. Consideration will be given to improvement of existing shelter facilities, or careful improvisation where necessary.

(2) One centrally located shelter will be designated for the Commanding General of the Wing. It will house the Central Control Point, and will be the action station for the RDO during any enemy attack on the base or vicinity. From this point he will direct activities of the base Radiological Defense Organization.

(3) In addition, shelters for necessary unit functions and personnel will be dispersed throughout each unit area.

(4) These shelters will be gasproofed where possible. They will be stocked with emergency food and water supplies, and will also house unit radiation detection instruments in at least one shelter per unit.

(5) Shelter housing the Central Control Point will have emergency radio and telephone communication with unit commander shelters.

(6) Slit trenches, covered with planks and banked with earth, and with blast walls protecting entrances will be provided near working and living sites for the accommodation of personnel unable to reach or use main shelters in event of attack.

b. Decontamination Centers. The normal bathing facilities of each unit will be used for personal decontamination. A monitor will

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be assigned to each such point to check personnel for radioactive contamination, should use of such facilities be necessary.

c. Dispersion.

(1) The Base Commanders will arrange through local Civil Defense Organizations for storage facilities at some point at least five miles from the base, and away from any industrial concentration. Upon direction from higher headquarters, these facilities will be used for storage of three days rations (packaged), water, emergency medical supplies, and tentage.

(2) This point will be designated as Emergency Evacuation Rendezvous, should evacuation of the base be necessary. Prevailing winds will be taken into consideration in selection of this point to insure, as far as possible that fall-out from an atomic bomb on any local potential target or on the base itself will not endanger the Evacuation Rendezvous.

4. Current Operation of Radiological Defense

a. Unit commanders will institute radiological defense training programs, including continuing indoctrination and training of new personnel. Unit commanders will maintain continuing check on defense measures within their units.

b. Each unit will prepare and maintain a list of priorities for evacuation of equipment in event such action becomes necessary.

c. Provisions will be made for an alternate field to be used by Wing aircraft should contamination or damage to runways render the base unusable.

d. Each unit will have one SO and two RM's trained at schools to be established at Wing level. These in turn, will train additional necessary monitor personnel within their units. In accordance with USAF policy, unit gas personnel will be detailed for such assignments in most instances.

e. Duties of the RDO

(1) The RDO will conduct initial training, and such additional training as may be necessary to maintain proficiency of SO's, RM's and general personnel in Radiological Defense.

Inclosure 1 to Annex 1

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(2) The RDO will conduct monthly inspection of the state of radiological defense training, equipment, organization, supplies, and facilities of Wing units.

(3) The RDO will conduct a monthly CPX in which the Radiological Defense Organization will participate. Emergency communications system will be used exclusively. Problems will be set, and the solutions thereto worked out by the Radiological Defense Organization. Every effort will be made to make these exercises as realistic as possible.

(4) The RDO will advise the Commanding Officer on exercises to be held quarterly, with all personnel participating, to test operations of defense measures.

(5) The RDO will maintain liaison with local Civil Defense authorities, for such mutual assistance as may be required. It will be understood that in event of attack the base can furnish no assistance to the local civilian population until all operation requirements have been made.

5. Warning System

a. Telephone warning of impending or possible attack will be given key personnel (Unit CO's, SO's, RM's, and leaders of Damage Control Groups) as far in advance of attack as possible ("Warning yellow" for possible, "warning red" for impending attack).

b. Attack alarm will be the prolonged rising and falling note of the base siren.

c. Radiological Attack Alarm will be a series of three short blasts on the siren, repeated at intervals. (This signal will also be used for chemical and biological attack.)

d. Evacuate Base will be signalled by a series of five short blasts on the siren, repeated at intervals, or by repeated firing of two green flares should the siren be inoperative.

e. All Clear Signal will be a prolonged single note on the siren. (Personnel will be warned not to leave shelters until rapid survey of the area is made, and unit SO's give the order.)

6. Measures to be Taken in Event of Outbreak of War

a. Gas masks and other available protective equipment (individual flash-burn protective covers, for example) will be issued to troops, and will be carried or kept at hand at all times.

Inclosure 1 to Annex 1

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Installation Radiological Defense Plan (Cont'd)

b. Maximum dispersion of planes will be maintained at all times. Available foliage cover will be utilized. Revetments will be constructed for single engine and other small planes. An emergency two-mission supply of gasoline and ammunition will be kept in the vicinity of each plane as a reserve, but normal stocks will be utilized for daily operation.

c. Stocks of bombs and ammunition will be dispersed as widely as available area of the base will allow Wooded areas will be utilized where possible.

d. The Transportation Squadron will disperse vehicles as directed; no concentration will be allowed at any time. Any reserve vehicles will be pooled at the Evacuation Rendezvous. The Transportation Officer will maintain a plan for control of his dispersed personnel and vechicles.

e. The Food Service Squadron will disperse food supplies in two or more locations on the base.

f. Supplies of gasoline on the base will be kept at a reasonable minimum, depending upon local circumstances. Since outbreak of war will almost certainly mean gasoline rationing, local civilian storage facilities may be made available where their location renders them suitable for their use.

g. The Wing Surgeon will designate a school, church, or other public building near the Evacuation Rendezvous as an emergency hospital, and it will be stocked with such supplies as might be required for treatment of radiation sickness along with other standard items.

h. The Wing Surgeon will coordinate duty requirements of base medical personnel, to the end that only those actually needed on duty will remain on the base. This is to insure that no single attack can wipe out all base medical personnel.

i. The Air Installations Officer will disperse a reserve of fire fighting personnel and apparatus to some point away from the base.

j. In event of enemy action within a fifty mile radius, the duty RM in each unit will make a quarter hourly check for radioactivity for the following eight hours. Any positive reading will be communicated direct to the RDO immediately.

k. If, an atomic bomb is dropped within a fifty mile radius, duty RM's will maintain this check until notified by the RDO that no fall-out can endanger the station.

Inclosure 1 to Annex 1

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l. The RDO will make a daily check with the Weather Officer to determine whether fall-out from an atomic bomb on any local potential target would affect the base itself or the Evacuation Rendezvous.

m. Film badges are issued to SO's and RM's and stocks readied for general issue.

7. In Event of Attack on Base or in Vicinity

a. All personnel not directly engaged in getting planes into the air will take shelter at the Attack Alarm. They will take with them gas masks, helmets, canteens (filled), arms and first aid packets.

b. Personnel of the Radiological Defense Organization will proceed to duty stations. (Command or other shelters as designated.)

c. The RDO will proceed immediately to the Central Control Point, and report to the CO or his representative. He will then establish communication with the unit command Control Points, and receive any preliminary reports. He will make a check with the Weather Officer on fall-out possibilities from a bomb or any local target. If dangerous contamination is anticipated, the CO will be so notified.

d. The SO's in each unit, immediately the attack has passed, will send out monitors and assistants (as runners, recorders, etc.) to each sub area of the unit area. A quick reconnaissance will be made, and results of this reconnaissance, including radiation danger areas and physical damage, communicated back to the SO and through him to the RDO.

e. Unit Area Damage Control Groups will go into action immediately after the attack has passed, each group accompanied by one or more monitors. Group leaders will report situations as soon as possible to the SO who will transmit reports to the RDO.

f. The RDO will assess reports, and as soon as possible present a report to the CO, with recommendations for action. He will divert assistance from unaffected areas, if any, to those requiring it.

g. Should preliminary survey reports indicate necessity for evacuation of the base, the CO is so advised, and necessary steps taken upon his decision.

Inclosure 1 to Annex 1

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Installation Radiological Defense Plan (Cont'd)

h. Monitors, meanwhile, if preliminary check has shown only mild or spotted contamination, will make a thorough survey of the unit areas, and direct the isolation and suitable marking of those areas found to be dangerous. Detailed information will be transmitted to SO's who plot readings on unit area maps, and transmit to the RDO. If highly dangerous contamination exists over a large part of the unit area, the fact is reported.

i. The RDO reports final state of the base to the CO as soon as full information is available, listing areas that are dangerous, the time men can work in them, and physical damage done. Should continued operation of the station be possible, the RDO then makes a personal inspection of each unit area to assist SO's as necessary.

j. Photodosimetry Laboratory begins operation, keeping necessary records under medical jurisdiction.

Inclosure 1 to Annex 1

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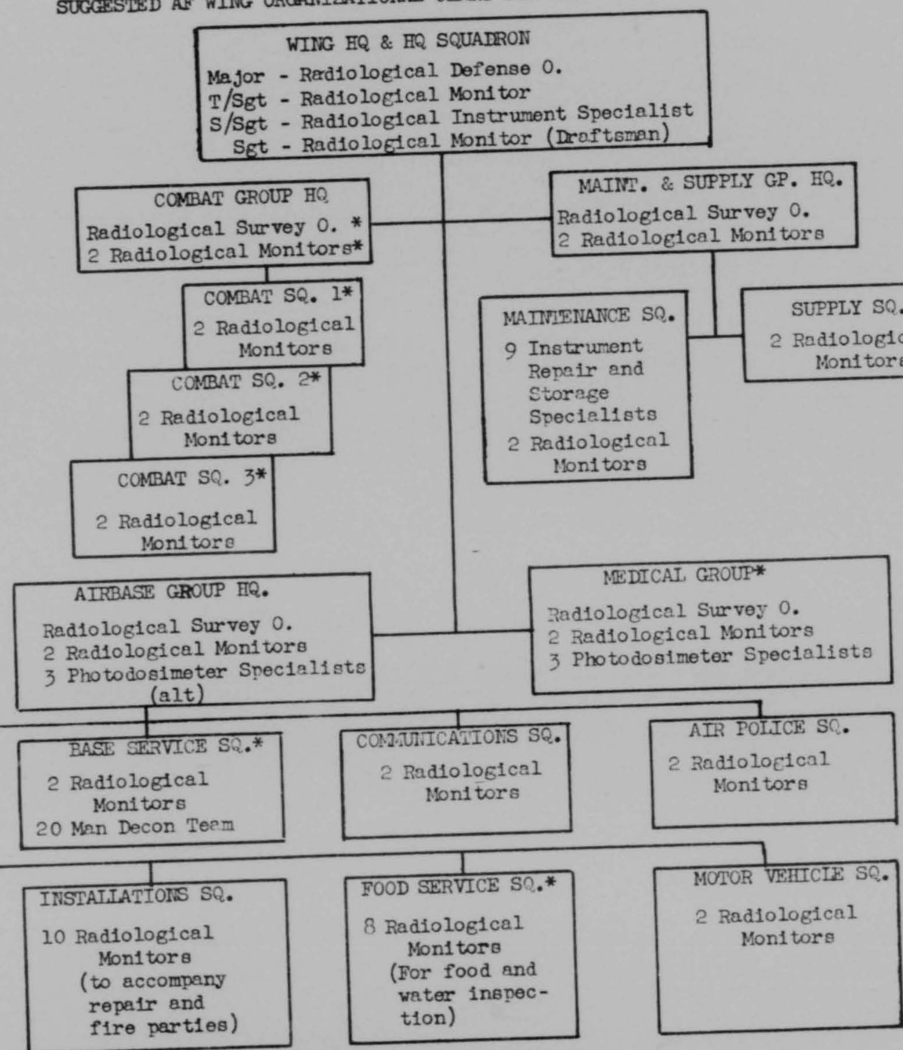
SAMPLE COPY

SUGGESTED AF WING ORGANIZATIONAL CHART FOR RADIOLOGICAL DEFENSE



Wing Hq. -Radiological Defense O. is his sole duty
Combat Hq. -Rad. Survey O. is additional duty for UGO & UGNCO's

CHART A (Inclosure 2 to Annex 1

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HEADQUARTERS
225th AIR COMPOSITE SQUADRON
Gamma Air Force Base, New York

UNIT RADIOLOGICAL DEFENSE PLAN

1. Radiological Defense Unit.

Lt. A, Survey Officer
T/Sgt B, Radiological Monitor
S/Sgt C, Radiological Monitor
Sgt D, Decon Squad Leader (10 designated EM)
Sgt E, Damage Control Squad Leader (10 designated EM)
Cpl F, Medical Non-com

2. Mission.

a. The unit CO is responsible for the radiological defense of this unit.

b. The Radiological Defense Unit is responsible for the co-ordination of the squadron activities in event of an atomic explosion or radiological attack. It will fulfill all of its responsibilities to the Base Radiological Defense Organization, and endeavor by all means possible to minimize casualties and damage in event of atomic attack.

c. It is responsible under direction of the CO for training and indoctrination of squadron personnel to insure accomplishment of the provisions of this directive.

3. Organization. The Survey Officer is responsible to the Squadron CO, and will advise him or direct activities upon approval of the CO. The Survey Officer will be guided by directions from the Base Radiological Defense Officer.

4. Warning System.

a. Provisions for defense will go into immediate effect with the signal for chemical or radiological attack (repeated series of short blasts on siren).

b. Crash alarm telephone system and any other method of communication possible will be used to further warn personnel.

5. Standard Operating Procedure.

ANNEX 2

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Unit Radiological Defense Plan (Cont'd)

a. Unit Radiological Defense Center.

(1) Upon sounding of alert, all radiological defense personnel will report to the Radiological Defense CP.

(2) All other personnel will take shelter unless engaged in activities immediately vital to the defense of the unit area against impending attack. Personnel taking shelter will have with them gas mask, proper protective clothing, weapons, and filled canteens.

(3) Instruments will be issued to monitors and final check will be made of this operating condition.

(4) Monitors will move out immediately after the attack has passed, and make a rapid survey of their areas of responsibility, reporting back to the Survey Officer as soon as possible. Survey Officer will transmit report of condition of his area to the Base Radiological Defense Officer as soon as possible. Monitors will then undertake detailed survey providing area is not too contaminated.

(5) Damage control and medical personnel will move out as soon as possible after the attack has passed and begin assigned operations, if this can be done without exceeding accepted tolerance dose.

(6) Necessary protective devices (film badges and pocket dosimeters) will be worn when required, and readings recorded.

(7) Continuing check of areas will be maintained and the CO notified of any changes of situation.

b. Further Duties of Monitors.

(1) Check food and water for possible contamination.

(2) Monitor equipment necessary in rescue and salvage operations.

(3) Monitor personnel requiring decontamination

c. Squadron Section Heads. Collect all personnel of sections:

Annex 2

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Unit Radiological Defense Plan (Cont'd)

(1) If within a contaminated area, remove to safe ground. See that men perform personal decontamination.

(2) If outside contaminated area, have men report to CP for assignment to any necessary special duty (i.e., to assist in evacuation, salvage, decontamination of equipment and supplies).

(3) Report to CO and/or Survey Officer for further assignment and special instructions.

d. Fire and Crash Crews.

(1) Follow Radiological Defense SOP.

(2) Fight fires as required.

(3) Assist in rescue and evacuation as necessary.

Annex 2

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TRAINING OUTLINE NO: 26

LECTURE: Tactical and Strategic Use of Atomic Weapons.

TIME: One hundred (100) minutes.

PLACE: Classroom.

INSTRUCTORS' REFERENCES: USSBS Report on Hiroshima and Nagasaki. (See Footnote*)

STUDENTS' REFERENCES: None.

TRAINING AIDS REQUIRED: None.

1. Introduction. Before we can arrive at a logical decision as to the significance of any new weapon, and atomic weapons in particular, we must be able to answer all six basic questions: who, what, when, where, why, and how? More specifically we must know the answers to the following questions about atomic weapons, viz:

a. What types of munitions are available now and in the immediate future?

b. What materiel and personnel effects will these munitions produce under a variety of possible conditions of use?

c. What psychological and political effects will this weapon produce?

d. What quantity and quality of munitions may be available?

e. What means are available now, or may be available in the near future, for launching this weapon, or placing radioactive materal on the target?

*Students should be informed that due to high classification of subject matter, this discussion must be in generalities.

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f. What are the actual and comparative costs of this weapon and other possible substitutes for accomplishing the same end-result?

g. What are the possibilities and influence of various protective and active defensive measures that can be taken on the target area before, during, and after an attack?

h. In view of the various possibilities and limitations of this weapon, what targets are likely to be selected for this weapon and how will the weapon be launched?

i. Much of the precise data we would like is not available. For instance, we do not know the precise intensity of nuclear radiation at 400 yards from an atomic bomb burst but we do know that this radiation is lethal to exposed personnel at one mile and may produce some effect at 3,000 yards when there is not shielding, and that shielding is proportional to the mass of material between the man and the source of radiations.

2. Explanation.

a. Types of munitions available and likely to be Used: The potency of the atom bomb has been demonstrated in controlled proving ground tests, as well as in war. We know that this munition is available to the United States at the present time. We doubt if it is available to any other nation in the world; but we can be certain that such a weapon will become available at some time in the future, perhaps five years or perhaps 25 years hence, but more likely within the next 10 years. We know also that one of the major steps in the manufacture of fissionable material for the atom bomb takes place in the so-called "chain reacting pile." Under the conditions existing in this device relatively large quantities of highly potent radioactive material are produced which cannot be used in the atom bomb.. The most potent of these by-products have a relatively short half-life, yet others of real potency have half lives of weeks and months. Therefore, it is entirely probable that highly effective radioactive dusts produced as by-products from the chain reacting pile are now available to a number of countries, and that such material will more than likely be available to all combatants in any future war. There is also a possibility that certain toxic gases containing arsenic and/or phosphorus, such as Lewisite or the so-called German nerve gases, might be made radioactive in a chain reacting pile and thereby produce a highly radioactive toxic gas. Such a material would be more difficult to produce than radioactive dust but it might offer some advantages in tactical use and the supply would be easier and much cheaper than atom bombs. These piles could operate near the combat zone to simplify supply.

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b. Effects of Atomic Munitions:

(1) The atom bomb really does not explode in the same sense as we speak of the functioning of a high explosive bomb. We normally think of an explosive as a sudden conversion of a solid occupying a relatively small space into an equal weight of gas at a very high temperature and high pressure tending to expand to occupy a very much larger space than that of the parent solid substance. Practically no gas is produced from the atom bomb but heat energy at the enormous temperature of several million degrees is produced in vast quantities. Much of this heat is dissipated from the point of reaction by radiation so that the surrounding air, ground, or water is heated to a very high temperature and functions in much the same way as the incandescent gas produced by the chemical reaction we normally associate with explosive phenomena but is more powerful because of the great quantity of energy released.

(2) The explosive wave set up by heating the surrounding gas or water is of longer duration in the air than is a corresponding true high explosive wave. Therefore the blast in air from an atomic bomb has more of the effect of a wind at super-tornado force, say 1,000 miles per hour, instead of a standard shock effect of very short duration which we associate with the high explosive bomb. There is a very material shock wave, however, when either the surrounding air or the surrounding water is heated suddenly to an enormous temperature.

(3) Whether or not the explosive wave would be of great significance if the atom bomb were caused to function in bone dry sand devoid of air is a matter of very interesting speculation. However, there is no question that a powerful underground explosion in ordinary earth would occur because of the enormous expansion of the moisture in the ground in the vicintiy of the bomb burst. Since no one has ever seen such a reaction this phenomenon of an underground burst will have to remain one of the unknown factors for some time to come, but it is safe to assume that a crater of extremely large proportions would be created and that the material within this crater would be atomized, rendered highly radioactive, and blown high into the sky as a dust cloud

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mixed with unfissioned matter. The heat produced would cause strong ascending air currents for a much longer period of time than would be the case with an air or water burst. The radioactive dust would fall out in an area downwind equal to several square miles of area and would render that area uninhabitable for some weeks and would be lethal to the inhabitants of the area unless they were promptly evacuated.

(4) The heating effect of an air burst atomic bomb is great and the radiant heat falling on combustible material or individuals within a range of about one mile will cause instantaneous fires in highly combustible materiel and may cause heat burns of a fatal nature to exposed personnel. The fires caused by radiant heat striking upon combustible material in the surrounding area and the fire wind associated with a huge fire will be the principal causes of materiel destruction from an air burst atom bomb. Buildings knocked down by the explosive wave may cause many secondary fires in the area. The air burst atomic bomb may be expected to destroy about three to four square miles of American urban area, but there would be little radioactive after-effect. You lose the radioactive after-effect if you get the instantaneous electromagnetic radiation effect of the air burst bomb.

(5) In addition to the heating effect, the prompt electromagnetic radiations produced by air bursts may be fatal to men through air at distances up to one mile if personnel are unshielded. When shielded by ten feet of earth this danger is reduced considerably.

(6) A perfectly enormous number of high velocity neutrons are shot out in all directions during an atomic explosion. Neutrons have a range of about one mile through air and are little affected by ordinary thicknesses of steel, lead, or concrete walls. Only massive thicknesses of earth would slow down and finally stop these neutrons. The effect of the neutrons is to induce radioactivity in calcium, phosphorus, salt, and other minerals in the human body and thus kill the individual by self-generated radiation. Beyond one mile the neutrons would be ineffective

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through air and their effective range through water and through the soil would be enormously decreased compared to their air range.

(7) Thus for all practical purposes we can say that the atom bomb produces:

(a) A powerful shock wave regardless of where or how it is exploded.

(b) Enormous heating of the surrounding medium, whether it be air or water, is produced by the atom bomb.

(c) In an air burst, powerful radiation effects are produced; but these radiation effects are considerably less on individuals beyond the immediate vicinity of the burst when the bomb is exploded underwater.

(d) An enormous quantity of radioactive materials are produced and blown into the surrounding medium. This radioactive material will fall out downwind for several miles, creating a definite fall-out hazard. This fall-out hazard, is minimized when the bomb burst is in the air because the radioactive cloud is dissipated into the upper atmosphere and the concentration of particles at points downwind is correspondingly reduced.

(8) Spraying an area with war gases such as mustard containing radioactive dusts or simply dusting the area with the by-products of a chain reacting pile would produce much the same effect as occurs in a fall-out.

c. Psychological and Political Effects of this Weapon: The atomic bomb, or radioactive dusts when properly used, would create an immediate local disaster which would necessitate hospitalization of large numbers of people for a prolonged period of time. Relatively few people would know initially the degree of radiation damage which they had sustained. This would tend to produce a mass hysteria. The psychological and political effect of the use of this weapon on a people would depend to a large degree on the people themselves and upon the propaganda countermeasures used to offset the effects of this weapon. In other words, the use of this weapon would make weak-kneed

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people surrender quickly without further effort, but it would spur a resolute people to far greater efforts. It will take very close study by highly competent experts in the subject to arrive at an evaluation of the psychological and political effects of atomic weapons on the people inhabiting a target area.

d. Number and Quality of Munitions Available: The production of atomic weapons is an extremely complicated and expensive process. In the future it may be possible to develop new methods for producing fissionable material from other than uranium ore. However we are limited, at present, to using these ores as raw material. These ores are scarce and in out of the way places other nations unfortunately have an appreciable portion of the known deposits within their jurisdiction. Fortunately certain countries, friendly to this nation, have very rich deposits of ore and these are our primary source of raw ore. At best, however, the total known amount of uranium ore is small. Therefore for the immediate and foreseeable future, the number of atom bombs available to any country for military purposes is going to be relatively small and these bombs are going to be exceedingly expensive. On the other hand, the amount of radioactive material produced in a chain reacting pile will be very much greater (probably in weight thousands of times greater than the actual fissionable material usable in atomic bombs) and such radioactive material can be produced by simply subjecting such things as table salt to neutron bombardment in a chain reacting pile. When, and if, this method is demonstrated it undoubtedly will be utilized to a much wider extent than the atomic bomb. Furthermore it is a very simple technical problem to operate a chain reacting pile compared to the production of fissionable material suitable for atomic bombs.

e. Suitable Targets for the Atomic Weapon:

(1) Any target to be worth the expenditure of an atomic bomb must have within a one mile radius of the point of detonation, large numbers of people, or national industrial installations of great strategic value. If an atomic bomb cannot be expected to kill or permanently disable and remove from the war several thousand people and destroy at least 100 million dollars worth of vital war materiel: or destroy industrial capacity that is vital to the war effort and which cannot be replaced in a reasonable time, then that target is not suitable for the expenditure of an atomic bomb. The one exception would be in a tactical situation of probable strategic importance.

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(2) An area consisting of a high density of population, expecially one of vital importance in producing war material, would be an ideal target for dissemination of radioactive dust or radioactive toxic gases because such an attack, even against a community having an ideal area damage control organization, would certainly disrupt production for a prolonged period of time and a large percentage of the people would absolutely refuse to return to their homes within the alleged danger area. Furthermore, a large city could be covered with patchwork contaminated areas, thereby increasing the effectiveness of this weapon. Therefore, dust or liquids containing radioactive material would be used mainly for their effect on personnel, whereas the explosive and incendiary effect of the atomic bomb would be used primarily against materiel targets with the anti-personnel effects as an added factor.

(3) Again we must state that targets might be selected which are of great military, political, or economical value. For instance, the portable harbor set up by Allied Invasion Forces on the coast in France was the life line of General Eisenhower's forces in France for a considerable period of time. One atom bomb dropped into this harbor would have destroyed it and rendered the shore and all shore installations, as well as large quantities of materiel on the shore, totally unfit for further use and highly dangerous to personnel in the area. By cutting the vital life line link at this point a single atomic bomb might have changed the course of the history of World War II in Europe. The Allied Invasion Forces for Southern France of the Seventh Army could have been eliminated by one atomic bomb in the Naples harbor at any time for a three-day period. However, for tactical purposes the atomic weapon must always be reserved for such special cases where there is an all-important bottleneck or all-important operation which, if destroyed, would enable the force of the nation using the atomic bomb to gain a distinct advantage.

(4) Atomic weapons therefore are essentially strategic weapons for the destruction of the economic heart of the enemy.

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f. Means and Weapons Available for Launching Atomic Weapons:

(1) A very large aircraft (B-29 or larger) is required to lift one atomic bomb. Therefore, such an aircraft, either piloted or pilotless, is required to drop an atomic bomb. No rocket or guided missile yet known to exist has the pay-load needed to take an explodable atomic weapon to the target. For instance, the pay-load of a V-2 German rocket is only 10 percent of that required to lift an atomic bomb. No doubt guided missiles can and will be developed capable of carrying an atomic warhead but this has not been accomplished.

(2) A ship could be used to place an exploding type atomic bomb in a harbor and such a weapon could be exploded later by radio waves or by a suitable delayed action mechanism, of which there are two or three suitable types. A submarine could be built to fire a torpedo carrying an atomic bomb in the warhead but torpedoes of such size are not made nor are submarines capable of firing such weapons in existance today without a major redesign.

(3) An atomic bomb could be constructed in place by saboteurs from material purchased commercially, except the relatively small weight of fissionable material and the trigger mechanism used in the heart of the bomb. Such material might be smuggled ashore from a foreign country.

(4) For scattering radioactive dusts and toxic gases we would need suitable bombs designed for air bursts. Actually such bombs would be gigantic M25 exploding hand grenades Such munitions would be loaded in special gliders and dropped from the glider by remote control. A thousand foot towline and shielding provided by ordinary bomb cases would provide safety for the crew.

(5) We can see from the foregoing discussion that the actual methods available for delivery of atomic weapons on suitable targets is somewhat limited at the present time, yet the variety is sufficiently great to make defense most difficult.

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g. Comparative Cost of Atomic Weapons and Other Munitions: It is not possible to state categorically the cost of destroying one square mile of area by means of the atomic bomb as compared with similar action by high explosive or by incendiary bombs. However, a very careful study of the area destroyed in Japan by various weapons indicates that one atom bomb (requiring one B-29 to carry it) produced destruction equivalent to 221 B-29s loaded with incendiaries or about 1,000 such planes loaded with high explosives. The cost of 220 B-29s and crews, of course, must be included in the cost of the incendiary attack while the cost of the larger number of planes and crews loaded with high explosives would have to be figured in this computation as well as the actual cost of the munitions used in each case. However, in all probability a lone plane can never again get to its target with an atom bomb because under such conditions jet fighters and rocket propelled defensive munitions would undoubtedly be concentrated in all areas likely to be attacked by atom bombs, and in order for the plane carrying the bomb to reach its target it would have to be guarded by an exceedingly strong escort of fighters and fighter bombers. Therefore, it would be futile at this stage to set down in dollars or man-hours or man-lives the comparative cost of destroying one square mile of urban area by the various weapons. However, it is sufficient to say that, regardless of the actual cost in dollars, the scarcity of fissionable material with which to make these munitions will, for a good many years, prevent their use on targets that can be erased effectively by other means.

h. Possibilities of Various Protective Measures That Can Be Taken:

(1) Before, During and After an Atomic Attack. A good survey, warning, and evacuation plan, with proper means for its implementation, will reduce the expected damage of an atomic attack on a target area by an appreciable amount. Therefore, the better the area damage control plan and organization the less successful an attack will be.

(2) If disaster control units, communication centers, medical facilities and command posts have been adequately dispersed under suitable shelters and have a sound defensive plan to guide trained personnel, then such targets will be much less helpless in the first hour following an atomic attack and appropriate damage control measures can be initiated at once.

(3) Target areas which are well protected by extremely fast interceptor aircraft, and antiaircraft units assisted by an adequate radar net are much less

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likely to be struck effectively by atomic attack. This type of active air defense will only by available to highly critical areas and is not effective against saboteurs.

(4) It is thus apparent that the defense of an area can be divided into two phases of equal importance, viz:

(a) Active defense measures.

(b) Passive defense measures.

i. Final Selection of Targets: In making a final selection of a target for atomic attack, due consideration will be given to the following factors:

(1) Chance of a successful attack.

(2) Casualties inflicted by an attack.

(3) Type and extent of physical damage.

(4) Psychological and political effects achieved.

(5) Effect on the industrial potential of a nation.

(6) Disruption of important military operations.

j. General Conclusions:

(1) Atom bombs are going to be few in number for some time to come.

(2) Radioactive dusts are likely to be available on a relatively large scale.

(3) Atomic attacks will be so expensive to launch that only targets of major tactical or strategical importance can be engaged and then only when the chance of success is very great.

(4) The decision to use atomic weapons AT ALL must be considered carefully by the highest military and political authorities: as must each target so engaged.

3. Summary.

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QUESTIONS FOR USE IN CONFERENCE FOLLOWING LECTURE:

a. What would be the difference in time required on a dusted area compared to an atom bombed area for casualties to appear?

b. What specific military operations carried out in World War II (other than those cited in the text) might have justified the expenditure of an atomic bomb for tactical purposes?

c. What reasons might cause an enemy to concentrate on radioactive agents rather than atomic bombs for military weapons?

d. What are the major logistical problems in supplying

(1) Atomic bombs?

(2) Powerful radioactive dust and liquids?

e. What types of targets would be selected for

(1) Air burst atomic bombs?

(2) Shallow water bursts of atom bombs?

(3) Dusting an area with radioactive material?

f. How can a knowledge of possible tactical and strategic uses of atomic warfare be used to plan both active and passive means of defense (Area Damage Control)?

g. Select five target in the U.S.A. in order of priority which you think an enemy might try to tom bomb or neutralize on outbreak of war. Consider: (1) the chance of the attack reaching the target, (2) the effects of the bomb: (a) materially, (b) psychologically, (c) politically, (d) militarily.

h. What psychological and political effect might be produced in the U.S.A. by ten (10) atomic bombs at the outbreak of war followed by one such bomb per month thereafter?

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TRAINING OUTLINE: 27

LECTURE: Training Programs.

TIME: Fifty (50) minutes.

PLACE: Classroom.

INSTRUCTORS' REFERENCES: None.

STUDENTS' REFERENCES: None.

TRAINING AIDS REQUIRED: Copies of Training Outlines No 6, 7, 14, 17, 19, 21, and 27.

1. It has been stated in previous lectures that many policy decisions in the field of radiological defense have not been made firm. Irrespective of this, it can be clearly appreciated that every individual within the National Military Establishment should receive indoctrination training in this field at the earliest practicable time. Individual unit instructors should be qualified now to conduct this indoctrination training.

2. The minimum amount of training mandatory is that amount which indoctrinates each individual to an understanding of explosion phenomena, radiological hazards and the defensive measures possible. All additional training is highly desirable and should be limited only by lack of equipment. Even this situation is being corrected and within one year each active Air Force base should have radiation detection instruments.

3. Many of the lectures which have been presented in this course can be used for indoctrination training. Copies of these lectures will be issued for permanent retention.

4. A suggested six hour indoctrination course for all officer and enlisted personnel is outlined below:

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Period No.	Subject	Time	Reference
1.	General Nature of Atomic Structure Background material necessary for understanding atomic energy film, "Tale of Two Cities".	1 hour	Annex 1 AMSM #74
2.	Explosion Phenomena The phenomena of an atomic explosion and hazards therefrom.	1 hour	CO # 6
3.	Personnel Hazards Effects of an atomic explosion on personnel.	1 hour	CO # 7
4.	Individual and Collective Protection Defensive meansures possible against atomic attack.	1 hour	CO # 21
5.	Radiation Detection Instruments Brief description and demonstration of operation of detection instruments (when instruments are available).	1 hour	CO # 14 CO # 17 CO # 19
6.	Radiological Defense Organization Training films "Operation Crossroads", "Operation Crossroads - Radiological Safety".	1 hour	Misc. film #1323 and #1396

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ANNEX 1

GENERAL NATURE OF ATOMIC STRUCTURE

1. Introduction. Until the blast of the first atomic bomb tested fused the sand of the New Mexican desert into a glass-like substance, man had depended on the sun for all of his energy. Man used fire of one kind or another to warm himself, to cook his food, and run his engines. Fire derives its heat, its energy, from the sun. When we burn wood, some of the solar energy is liberated -- energy stored up by the tree from the sun's heat while it was growing. In burning coal and oil and gasoline we do the same thing, because coal and oil and the gasoline made from oil are, like wood, vegetable matter which stored energy from the sun during growth and then decayed or petrified millions of years ago to lie dormant under the earth's surface with stored-up energy until man discovered that they could be burned and their energy released as heat. Even when we eat plants, our bodies transform the solar energy in the plants into human energy and tissue. Meat brings us such energy second-hand, for the animals whose meat we use ate vegetable matter. Also, the power we get from wind and water comes indirectly from the sun, for, without the sun's heat, water would freeze and never evaporate to form rain and rivers and waterpower, and air unwarmed by the sun contains no currents of shifting cool and warm air which we know as wind. But there is another vast source of energy in the universe which does not originate in the sun. Scientists learned many, many years ago that the energy existed but they did not know how to release it. The solving of this problem and its potential uses have become a matter of utmost importance to the world.

2. The New Source of Power.

a. From the day of President Truman's dramatic announcement on 6 August 1945 that a bomb of unprecedented violence had all but obliterated the city of Hiroshima in Japan we have heard more and more about atomic bombs, atomic energy, fissionable materials, and the Atomic Age. The development of atomic energy was a discovery that is certain to affect not only the future development of the Air Force and the other armed services but also the course of our own lives and the lives of those who follow us.

b. Atomic power has already added many new words to our vocabularies. But not yet have we reached the point where a basic understanding of atomic energy is common knowledge. What is an atom? How is it constructed? Exactly why has the unlocking of the secret of the atom brought into the world tremendous possibilities for future good or evil? These things must become more commonly understood if we as Americans are to make correct decisions on the uses in which atomic energy may be put, and if we as members of the armed

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forces are to gain an understanding of what the atom can mean in possible future warfare.

c. The structure of the atom and the sources of atomic power are somewhat complicated but not impossible to understand. Comprehension of the fundamentals does not require a high degree of education.

d. This new source of energy is in matter itself. In order to understand it we must first learn how matter - all matter - is constructed. We must also change some of the ideas about matter and energy that have been believed for hundreds of years - ideas that have been taught, for example, in high school physics.

e. Two supposed rules on the behavior of matter are now changed - the laws of conservation of mass and conservation of energy. The law of conservation of mass held that matter could neither be created nor destroyed, that it can only be altered in form. Thus when we burn a piece of coal, we do not destroy the matter that forms the coal; we only convert it from coal into gases and ash. The law of conservation of energy likewise holds that energy can neither be created nor destroyed but can only be changed in form. Thus, when we burn the piece of coal we merely set free in the form of heat and light the energy that the coal soaked up from the sun millions of years ago.

f. But in 1896 a French physicist, Becquerel, discovered that an element called uranium gave off energy by itself. Two years later the Curies, French scientists, discovered the same properties in radium. The energy given off by these and similar heavy elements of matter is called radioactivity.

g. It was this discovery of radioactivity that led to our tapping the energy bound up in matter, which up to the present time has been released in practical form only in the atomic bomb. We now know that matter and energy are but two manifestations of the same thing, and that under certain conditions matter can now be converted directly into energy and vice versa.

3. The Amount of Energy or Power in Matter.

a. When an atomic bomb explodes a certain amount of matter, as such, disappears. It is transformed into energy. After each explosion there is a little less matter in the world. Thus the old separate laws of conservation of mass and energy no longer hold true. Neither matter nor energy can be completely destroyed. But one can be transformed into the other.

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ANNEX 1 (Cont'd)

b. To comprehend this, we must also revise our ideas about what happens to matter and energy even in ordinary chemical reactions, or changes in matter, such as the burning of coal or the explosion of TNT. It was long believed that when a piece of coal is burned the total of the weights of the gases and the ash produced were exactly equal to the ori-nal weight of the coal.

c. For all practical purposes this is still true, because the percentage of the weight of the coal transformed into heat and light, or energy, is so extremely small that it cannot be measured with any instruments now at our disposal. But what the scientists have learned about the transformation of matter into energy has made it possible to calculate with some accuracy the very small amounts of matter turned into energy by ordinary fire. Professor Albert Einstein, in his famous theory of relativity, devised a formula to determine the amount of energy contained in a given amount of matter. By comparing the amount of energy derived from the burning of a given quantity of coal with the greater amounts of heat given off by a given quantity of radium we can tell exactly how much of the coal actually turns into energy. In all normal chemical processes the percentage is infinitesimally small.

d. The Einstein formula in brief form is this: One pound of matter, any kind of matter inanimate or living, equals 11,400,000,000 kilowatt-hours of energy. The correctness of this method of calculation has been proven conclusively. From it we find that if the energy contained in one lump of coal could be completely liberated it would be about three billion times the energy obtained by burning the coal. The total energy of some twenty-five pounds of matter is equal to all the power produced in the United States in a year's time.

4. How Matter is Constructed.

a. Long ago the early Greek philosophers believed that all matter was composed of tiny indivisible particles to which they gave the name of "atoms". Their arguments were based only upon shrewd observation and were not confirmed by scientific experimentation. It was not until the eighteenth century that scientists found concrete scientific evidence to prove the "atomic hypothesis." The proof was found that all of the several hundred thousand substances found in nature are made up of very small particles called molecules.

b. The molecule is the smallest division of matter that allows a given substance to retain its identity and characteristic properties. For example, a molecule of sugar is the smallest particle into which sugar can be separated and still be sugar. There are several hundred thousand different molecules that occur naturally. Chemists have made hundreds of thousands more.

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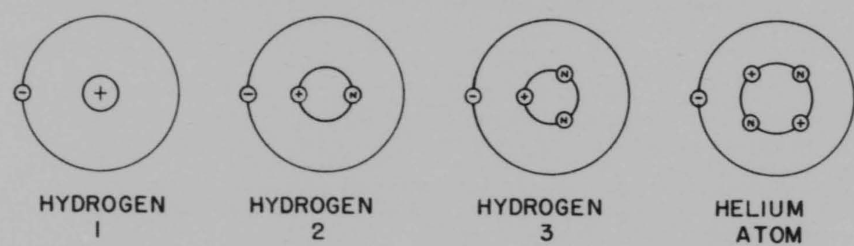
ANNEX 1 (Cont'd)

c. But although there are hundreds of thousands of molecules, all of them are combinations of only 92 simpler "elements" and several hundred "isotopes" of these elements, plus a few more recently discovered unstable elements. Elements are materials which cannot be broken down into simpler substances by chemical means. Water, for example, can be divided by chemical process into two elements, oxygen and hydrogen.

DIAGRAM OF HYDROGEN ISOTOPES COMPARED WITH HELIUM ATOM



d. The smallest unit of an element -- that is, the unit which cannot be subdivided without becoming something else -- is called the atom of that element. Some common examples of elements are hydrogen, carbon, nitrogen, oxygen, iron, copper, silver, gold, platinum, mercury, and many others. We can talk about atoms of these elements. But sugar, for example, is not an element, because a molecule of sugar contains many atoms of carbon, many of oxygen, and many of hydrogen. A molecule of water actually consists of two hydrogen atoms (H is the chemical abbreviation for hydrogen) and one oxygen atom (O), and is represented by the familiar chemical formula H_2O. Salt is not an element but a combination of two elements -- one sodium atom (Na) and one chlorine atom (Cl) and is represented by the formula NaCl.

e. But even after atoms and molecules had been discovered, it was not clear why, for example, the two atoms of hydrogen would combine with one of oxygen to form a molecule of water. The reason for this combination into molecules was discovered in the second decade of the present century, when it was found that atoms were divisible and had complicated structures of their own.

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f. Atoms might be compared with minute solar systems, with a heavy central core, or "sun" called the nucleus. This central nucleus consists of one or more "protons". Around the nucleus, at relatively great distances from it, revolve much lighter particles, called "electrons". A proton weighs 1836 times as much as an electron.

g. This whole atomic "solar system" is very tiny; about one billion atoms could be lined up on a one-foot rule. Yet the size of the atom is enormous compared with the size of the electron. The average distance of the electron from the nucleus is about one hundred thousand times as great as the diameter of the nucleus. Hence every atom consists mostly of empty space.

h. The central nucleus of the atom is from two thousand to five thousand times heavier than its surrounding electrons. Actually, more than 99.9 percent of all the matter in the world is concentrated in the central nucleus of the atoms of the 92 basic elements.

i. In addition to size and weight, an electric charge is a very important quality of the electrons and nucleus of an atom. There are two kinds of electric charge -- positive and negative. Electric charges of the same kind -- either positive and positive or negative and negative -- repel each other. Charges of opposite kinds -- positive and negative -- attract each other.

j. An electron carries the smallest unit of negative electricity that has ever been observed. The unit of measure of the flow of electricity (electric current) as we ordinarily know it and use it for light, heat, and power is the ampere. One ampere is a small current. But the charge of an electron is so much smaller that it takes the flow of more then six million million million million electrons per second to make one ampere. This tiny electric charge of one electron is used as the unit of measurement to state the electrical properties of atoms.

k. The element hydrogen has the simplest atom. The hydrogen atom has one electron revolving around its nucleus. Its nucleus consists of one proton. The proton carries a positive charge of electricity which exactly balances the negative charge of the electron so that, electrically speaking, the atom as a whole is neutral.

l. The nature of each of the 92 elements is determined by the number of protons in the nucleus of its atom. Thus, the hydrogen nucleus has one proton, the helium atom two, the lithium atom three, and so on up the atomic scale until we arrive at the nenety-second element, uranium, which has 92 protons in its nucleus.

m. Since each proton contains one charge-unit of positive electricity, the number of protons in the nucleus determines the number of electrons which revolve around the nucleus. The number of revolving electrons always balances exactly the number of protons in the nucleus.

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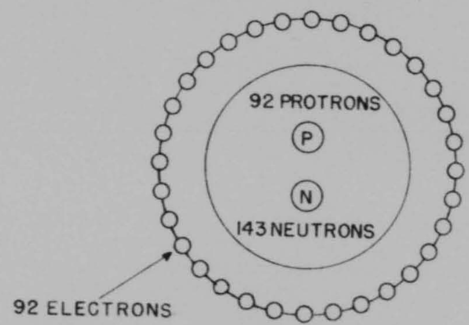
ANNEX 1 (Cont'd)

n. The number of protons in the nucleus also determines the atomic number of the element. Thus hydrogen, with one proton in its nucleus, has the atomic number 1, helium has number 2, and so on up to uranium again, which has the atomic number 92.



o. If we can picture to ourselves the structure of the atom with its central nucleus of one or more heavy protons, and one or more much lighter electrons revolving about the nucleus, we can understand nearly all of the physical and chemical properties of matter.

p. But it is not quite as simple as that. Nature has departed from consistency in certain elements. With the discovery of radioactive elements, such as radium and uranium, it was found that such types of matter had surprising properties that could not be explained on the simple basis of balanced nuclei and electrons. The ability of uranium and radium to give off energy in the form of rays (some of which were identified as fast-flying nuclei of an entirely different element, helium) indicated that the atoms of radium and uranium and similar elements were actually undergoing changes deep within their nuclei. These changes are known as radioactive decay, which is really the emission of various forms of excess energy. Alpha radiation, beta radiation and gamma radiation are the three forms in which this energy is emitted.

q. An even more surprising property of matter was discovered in 1919. It was found that the collision of helium atoms with nitrogen atoms led to the formation of two entirely different atoms -- oxygen and hydrogen. This actual change of one element into another, which was as startling and remarkable as changing iron into copper or lead or silver, could only be explained by assuming that the nucleus of an atom could be divided and other elements thus formed.

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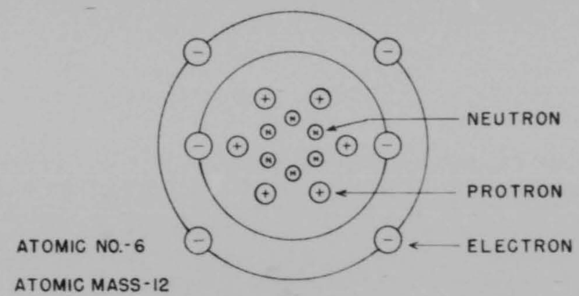
ANNEX 1 (Cont'd)

r. In 1932, a new particle, the neutron, was discovered within the nucleus of the atom by Professor Chadwick, of Cambridge University. The neutron is electrically neutral. It possesses a tremendous amount of energy.

s. The protons and neutrons which form the nucleus of an atom differ markedly in electrical properties, but they have nearly the same weight. The weight of a neutron like that of a proton is about two thousand times that of an electron. Since the weights of the proton and neutron are about the same, and the weight of the electron much less, the weight of the atom is very close to that of the total number of neutrons and protons in the nucleus.

t. The total number of protons and neutrons in the nucleus of any atom is called the atomic mass, or mass number, of the particular element. For example, carbon has six protons in its nucleus, giving it the atomic number 6. In addition the carbon nucleus contains six neutrons, so we say that carbon has the atomic mass, or mass number, of 12. To determine the number of neutrons in the nucleus of each element, we subtract the atomic number (that is, the number of protons) from the atomic mass number.

u. It has also been discovered that most elements may consist of mixed atoms of more than one form -- called "isotopes" -- in the sense that the number of protons in the nucleus is always the same, but the number of neutrons may be different. These isotopes have the same atomic number but different atomic weights. For example, there are three kinds of hydrogen, all called isotopes, all containing one proton in the nucleus of the atom; hence, all three have the atomic number 1. The first hydrogen isotope has no neutrons (the only element of its kind), and thus it has an atomic mass of 1. The second hydrogen isotope has one proton and one neutron and thus an atomic mass of 2; the third, with two neutrons, has an atomic mass of 3. (see diagram of hydrogen isotopes, page 5).



CARBON ATOM

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ANNEX 1 (Cont'd)

v. Likewise the uranium atom always has 92 protons; but uranium is found in nature in three isotopes, the nuclei of which have either 142, 143 or 146 neutrons (in addition to the 92 protons in each kind). Thus the three uranium isotopes have atomic masses of 234, 235, and 238 respectively.

5. The Forces Within the Atom.

a. We have seen that the nuclei of atoms are built of protons and neutrons. Before the discovery of the complex structure of the atomic nucleus it was believed that two general types of force could account for all natural phenomena; electrical forces, which account for lighting, radio, and television; and gravitational forces, which cause objects to fall to the earth and govern the motion of the planets around the sun.

b. The forces that hold together the particles in an atomic nucleus are due neither to electricity nor to gravity. For one thing, although neutrons have no electrical charge and protons do have an electrical charge, the holding force between two neutrons or between a neutron and a proton in the nucleus of an atom is the same as between two protons.

c. The exact nature of these nuclear forces is not yet clearly understood, but it is known that when protons and neutrons are at distances smaller than a million millionth of an inch -- the diameter of an atomic nucleus -- extremely strong forces of attraction between them come into play. The force that holds a proton or neutron inside the nucleus of an atom is more than a million times stronger than the electric force that holds an electron inside the atom itself, and this force in turn is much stronger than any gravitational force.

d. The strength of this nuclear force is best shown by comparing the weight of an atomic nucleus with the total weight of its separated protons and neutrons. The whole nucleus actually weight slightly less than its parts; it has about 99 percent of their weight. But from Professor Einstein we know that weight (or mass) and energy are equivalent and can be transformed into each other. Hence in a nucleus a small part of the weight of the protons and neutrons appears to become energy holding the nucleus together.

e. A tiny bit of matter is equivalent to an enormous amount of energy. Therefore the one percent difference between the weight of the nucleus and that of its separated neutrons and protons indicates that a tremendous amount of energy is stored in the nucleus. This is "atomic energy". The scientific problem, partly solved in developing the atomic bomb, was how to get some of this energy out of the atomic nucleus -- how to get it released -- in a practical, usable form.

6. Releasing the Energy of the Atom.

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ANNEX 1 (Cont'd)

a. According to the nuclear physicists, atomic energy can be obtained either by splitting the nuclei of heavy atoms into almost equal parts, or by building up heavier nuclei out of the nuclei of light atoms. So far it has been possible to obtain atomic energy only by "atom splitting". The building-up process, which accounts for the energy in the sun, requires such high temperatures that it is considered impossible for man to accomplish it on earth.

b. During the 1930's many investigators "split" the nuclei of atoms by building special scientific instruments and bombarding them with protons or neutrons. A separate proton directed or "shot" at an atomic nucleus tends to be repelled by the nucleus because the outside proton carries the same type of electric charge as the protons in the nucleus. Hence outside protons must have tremendous speed to overcome this repelling force and come close enough to the nucleus for a proton to hit it occasionally. On the other hand, a separate neutron directed at a nucleus has no electric charge. It is therefore not repelled and can more easily strike and penetrate the nucleus.

c. This is why the discovery of the neutron was of tremendous importance. It was use of the neutron that enabled the scientists to tap the heart of the uranium atom, releasing the energy that erupted so explosively in the atomic bomb. It is the neutron that will unlock further atomic secrets for us, opening up possibilities that at present can only be imagined. In the words of one scientist, the neutron is "the sword with which to open the cosmic oyster."

d. All the cases of atom-splitting up to 1938 have one result in common -- the bombarded nucleus split into two fragments. One was always very small while in the other was left most of the original nucleus. But in 1938 it was found that a heavy nucleus would split into two almost equal parts upon a neutron bombardment. In particular it was found that the nucleus of the uranium isotope of mass number 235 would split into two large pieces of almost equal weight. This real atom-splitting is called "nuclear fission".

e. Further investigations showed that nuclear fission liberated tremendous amounts of energy. The split nucleus lost about one one-thousandth of its mass by transformation into energy. We have already noted that a small difference in mass corresponds to an enormous amount of energy.

f. Even more important was the fact that during the fission process extra neutrons were released and these multiplied the effect of the original neutron bombardment. It is these extra neutrons that make it possible to release atomic energy in practical amounts. Without the additional effect of the released neutrons which strike and break up other nuclei, thus releasing still more neutrons, nuclear fission would be a comparatively rare event and the amount of energy released each time

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would be of no practical value. It would be as if a ton of coal needed thousands of dollars worth of matches to keep it burning.

g. The extra neutrons released in the fission process in turn produce fission in more nuclei, and this releases more neutrons, and so on. A large number of nuclei undergoing fission release large amounts of energy, and the repeating process is called a "chain reaction".

h. In order to cause a chain reaction, quite a big lump of fissionable material, such as uranium, must be used. If only a small piece is used most of the extra neutrons will escape from the lump and not enough will remain within it to keep the reaction going. But the comparative number of neutrons that escape can be reduced by increasing the size of the lump of the material. This is because the production of neutrons is proportional to the volume, whereas the escape of neutrons is proportional to the surface area and the volume increases more rapidly with size than does the surface area.

i. As the size of the lump is increased a point is reached at which there are as many neutrons produced by fission as escape through the surface of the lump. This amount is called a critical mass. Any amount of the material smaller than a critical mass is not enough to keep a chain reaction going. On the other hand, if the amount is greater than a critical mass, more neutrons will be produced than leak out and an explosion may result.

j. Whether or not there is an explosion depends on whether the chain reaction develops in a short enough time. If the mass of active material is made strongly over-critical, the chain reaction develops very rapidly. Energy is then released at an explosive rate and the active material expands until it becomes diluted. With the dilution of the active material more neutrons escape and in time the reaction stops. But during the short time before expansion stops the chain reaction a large number of nuclei undergo fission resulting in a tremendous release of energy and a violent explosion. This is what happens when an atomic bomb is exploded.

k. If the amount of active material is only slightly over-critical the chain reaction develops slowly. Then it can be controlled and the energy can be released at a slow, even pace. It is this controlled chain reaction that offers hope for future uses of atomic energy for peace-time purposes.

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TRAINING OUTLINE NO:	28
LECTURE:	Effect of the Atomic Bomb on Hiroshima Nagasaki.
TIME:	One (1) hour.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	USSB Report on Hiroshima and Nagaski; "Medical Aspects of Nuclear Energy", AFSWP, NME, 1949; Chapter 12, 13 and 14, "AFRTC Manual 52-355-1", Dept of the Air Force, May 1949.
STUDENTS' REFERENCES:	None.
TRAINING AIDS REQUIRED:	Charts appended hereto.

To determine the basis on which the probable effects of an atomic weapon can be predicated we can best study the effects of the weapon on Japan. Consideration of the conditions existent when the attack was delivered and an evaluation of the damage resulting therefrom will help us greatly to predict the probable effect of an atomic weapon on some strategic target within the United States. Consideration will be given to Hiroshima and Nagasaki separately and overall conclusions drawn from both.

1. HIROSHIMA

a. General. The city of Hiroshima was selected as a target for the first atomic weapon because it had received an insignificant amount of prior bomb damage, was on a flat level delta, had representative structural types of construction located over a large area, contained predominately over-crowded wooden buildings, was well equipped with public utilities and services, and was an important military center.

b. The Target. Hiroshima covered an area of approximately 26.5 square miles and had a population of about 245,000. However in the central portion of the city there was a population density of over 31,600 persons per square mile. This density is about 1¼ times the density of New York City despite the fact that Japanese dwellings are not over two stories high. The central portion of the city was devoted to residences, commercial sections and military installations but had no industrial establishments of any size. All houses were equipped with electric lighting, about 75% of the

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residences were supplied with gas for domestic consumption, all residences had water connections to the municipal system but there was no sewer system. The city was built on a flat delta and divided into five islands by the Inland Sea. These islands were connected by forty-five bridges and the streets were wide enough for two lanes of traffic. There were few firebreaks, those which existed were inadequate in width, the fire department was small and poorly equipped and no well organized civilian defense units were functional. There were eight major hospitals in the city.

c. Circumstances. The morning of the attack was clear with a 4 mph wind. At 0709 hours an air raid alert was sounded but only a few planes came over and at 0731 hours the "all-clear" was sounded, since the B-29s were thought to be reconnaissance planes only. Following this, people were on their way to work when planes arrived over Hiroshima at 28,000 feet and dropped the atomic bomb. As a result almost 75% of the population was in a congested 4 mile square area of the city's center at the instant of detonation. In addition there had been no rain in three weeks and the area was dry.

d. Action. At the instant of detonation there was a blinding flash more brilliant than the sun. Following this flash there was a blast of heat and wind. The large majority of people within 3,000 feet of the explosion were killed immediately. Within a radius of about 7,000 feet almost every building collasped. Beyond 7,000 and up to 15,000 feet - 20,000 feet many buildings collasped and others received serious structural damage. Persons in the open were burned on exposed surfaces, and within 3,000 - 5,000 feet many were burned to death while others received severe burns through their clothes. In many instances clothing burst into spontaneous flame. Thousands of people were pinned beneath collapsed buildings or injured by flying debris, particularly flying glass. Fires began to spring up over the city and developed into a fire storm in the center of the city. Some of these fires were caused by direct ignition of thatched roofs, curtains and rubbish but the majority resulted from secondary effects such as debris falling on kitchen fires, electrical short circuits and industrial process fires. For half an hour the fires spread in all directions, thereafter they merged, and burned out all combustible material in an area of 5 square miles. The fire department was paralyzed and survivors, becoming panicky, fled to the outskirts of the city.

e. Damages.

(1) Buildings - Of 90,000 buildings spread over an area of 9.5 square miles, some 60,000 were totally or severely damaged. Roofs and walls were stripped from other buildings 4 miles from the explosion and glass windows were broken up to 8 miles.

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(2) Public Utilities - All utilites and services were disruptedand damaged, a great many key employees were killed, and the city was temporarily without transportation, electricity, communications, gas, water or effective authority. Thirty hours elapsed before the first rescue or relief parties entered the stricken areas.

f. Casualties. Approximately 80,000 persons were killed outright, almost another 100,000 were injured of whom some 60,000 died in the next two months and only about 50,000 remained uninjured. Deaths were due to the following causes:

(1)	Radiation disease	15 - 20%
(2)	Flash burns	20 - 30%
(3)	Secondary injuries	50 - 60%

Radiation effects were very prominent up to 6,500 feet and personnel within a radius of 3,000 feet would have been killed by radiation sickness later had they not been killed outright due to blast, burns and debris. All medical facilities and most of the medical personnel in Hiroshima were destroyed. The injured who survived did so without any appreciable medical care, however it is estimated that not more than 10% of the terminal casualties could have been saved by the best of medical care.

2. NAGASAKI

a. General. The second attack involving an atomic weapon was initially directed against an unknown city but weather closed in and Nagasaki, an industrial city, was hit. Five previous HE bomb attacks had produced negligible damage.

b. Target. Nagasaki covered an area of approximately 35 square miles, of which 4 square miles was heavily built-up, and had a population of some 230,000 persons. The city lay on a narrow coastal strip encircling a long narrow bay and extending up two river valleys which were separated by a mountain spur. One of these spurs contained the industrial zone, while the other contained the residential and commercial areas. Information on electrical, water and gas connections to residences is not available. The city was haphazardly built and the street system was poor. Firebreaks were inadequate and the fire department was inferior. Over 90% of the available hospital facilities were concentrated in two hospitals.

c. Circumstances. The day of the attack was clear with a 3 mph wind. An air raid alert was sounded at 0750 hours but was cancelled at 0830. No warning was sounded at 1102 hours when the aircraft came over and dropped the bomb.

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d. <u>Action</u>. The bomb detonated in the air and the results were generally the same as at Hiroshima. The blast was not centered over the main business area of the city but up the valley about two miles where there were industrial plants, hospitals and partially built-up residential areas. The terrain in this area was uneven with large hills which shielded certain areas. Due to the shielding factor and distance of the explosion from the city, Nagasaki was not as completely destroyed as Hiroshima. There was no fire storm and not nearly as much panic as at Hiroshima but there was greater damage within the blast area. The fire department was unable to cope with fires but bucket brigades were effective in some areas.

e. <u>Damages</u>.

(1) Buildings - Some 20,000 buildings in an area of 1.8 square miles were destroyed or severely damaged. Structural damage due to blast extended some 6,000 feet - 7,000 feet north and south of the explosion. Superficial and minor damage due to blast extended as far as 19,000 feet along the bay and extended to valleys protected from the direct blast.

(2) Public Utilities - All utilities and services were disrupted and damaged as at Hiroshima. The destruction was not so great, however, and restoration of limited service was quicker.

f. <u>Casualities</u>. About 45,000 people were killed and some 60,000 injured in about the same ratio of casualties as were noted at Hiroshima. All hospitals and almost all medical personnel were destroyed. It was several days before any organized medical care was instituted..

3. CONCLUSIONS

a. <u>General</u>. Detailed evaluation of all available data from the bombing of Japan has not been released. Certain general rules can be drawn however. These rules are summarized below.

b. <u>Effect of Explosion</u>.

(1) Blast or pressure wave similar to normal explosion except in degree of magnitude.

(2) Primary fires which are those started instantaneously by the heat radiated from the atomic explosion.

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(3) Secondary fires which are those resulting from the collapse of buildings, damage to electrical systems, overturning of stoves and industrial process fires.

(4) Spread of primary and secondary fires to other buildings.

c. Radius of Blast. With the exception of certain reinforced concrete structures, everything within 1,000 yards from the center of the explosiion will be totally destroyed. Portions of strong concrete structures may survive the blast but will be useless. Everything up to three miles will suffer considerable damage and beyond this distance damage, although comparatively light, may extend for six to seven miles. Glass may be broken up to ten miles. Details are shown on the following chart.

(INSTRUCTOR - REPRODUCE CHART 28-1)

d. **Fire Damage.** A vast quantity of radiant energy is released at the instant of detonation. This radiation causes intense surface heating of all objects up to two miles from the center of the explosion. In some cases this surface heating will ignite readily flammable material. The majority of fires, however, are due to secondary causes. Depending on the wind, effectiveness of fire breaks and action of disaster control personnel, these fires may be contained or allowed to spread and become a conflagration which burns out areas untouched by the blast. More specific data are included on the following chart.

(INSTRUCTOR - REPRODUCE CHART 28-2)

e. Effects of Radioactivity.

(1) Prompt - All persons within about 1 mile of the center of the explosion will receive a fatal dose of gamma and neutron radiation. They will, however, most likely be killed outright by heat, blast or debris. Those in an area between 1 and 1.5 miles from the explosion will receive an appreciable dose of radiation that, while not necessarily fatal will complicate recovery from other injuries. Outside the 2 mile radius there is little effect from instantaneous radiation.

(2) Residual - A high airburst detonation will leave negligible residual radioactivity and may be confined to some neutron induced radioactivity directly under the blast. However, fall-out of radioactive particles from the cloud will occur and may do so many miles away in

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dangerous amounts. If detonated on the ground, small areas up to one mile in radius from the center of detonation may be heavily and semi-permanently contaminated, thereby necessitating abandonment.

f. Casualties. Unless personnel were dispersed in underground shelters a minimum of 100,000 casualties would probably result in an area such as New York City and some 25,000 - 50,000 would be killed outright. The bulk of all medical facilities would be destroyed as well as medical personnel.

4. CONCLUSION

The atomic bomb is a weapon without parallel in destructive power. Its effect on Japan was to destroy two cities and break the will of the Japanese nation to wage war. A large portion of its effectiveness was due to the overwhelming surprise of a new weapon, the inferior passive defense organization and the fact that personnel were not dispersed in air raid shelters. The effect of an atomic bomb on other cities and nations could be similar to that on Japan. However it is felt that a disciplined populace well organized and prepared for atomic attack could greatly minimize the effect of an atomic attack.

INSTRUCTOR'S QUESTIONS:

1. What percentage of atomic bomb casualties are due to radiation injury? What percent to burns? What percent to secondary injuries?

2. What will happen to every man-made structure within 1,000 yards of an atomic explosion?

3. How far does appreciable blast damage extend from an atomic explosion?

4. How far do intense surface heating effects extend from an atomic explosion?

5. How far is the prompt radiation from an atomic explosion dangerous?

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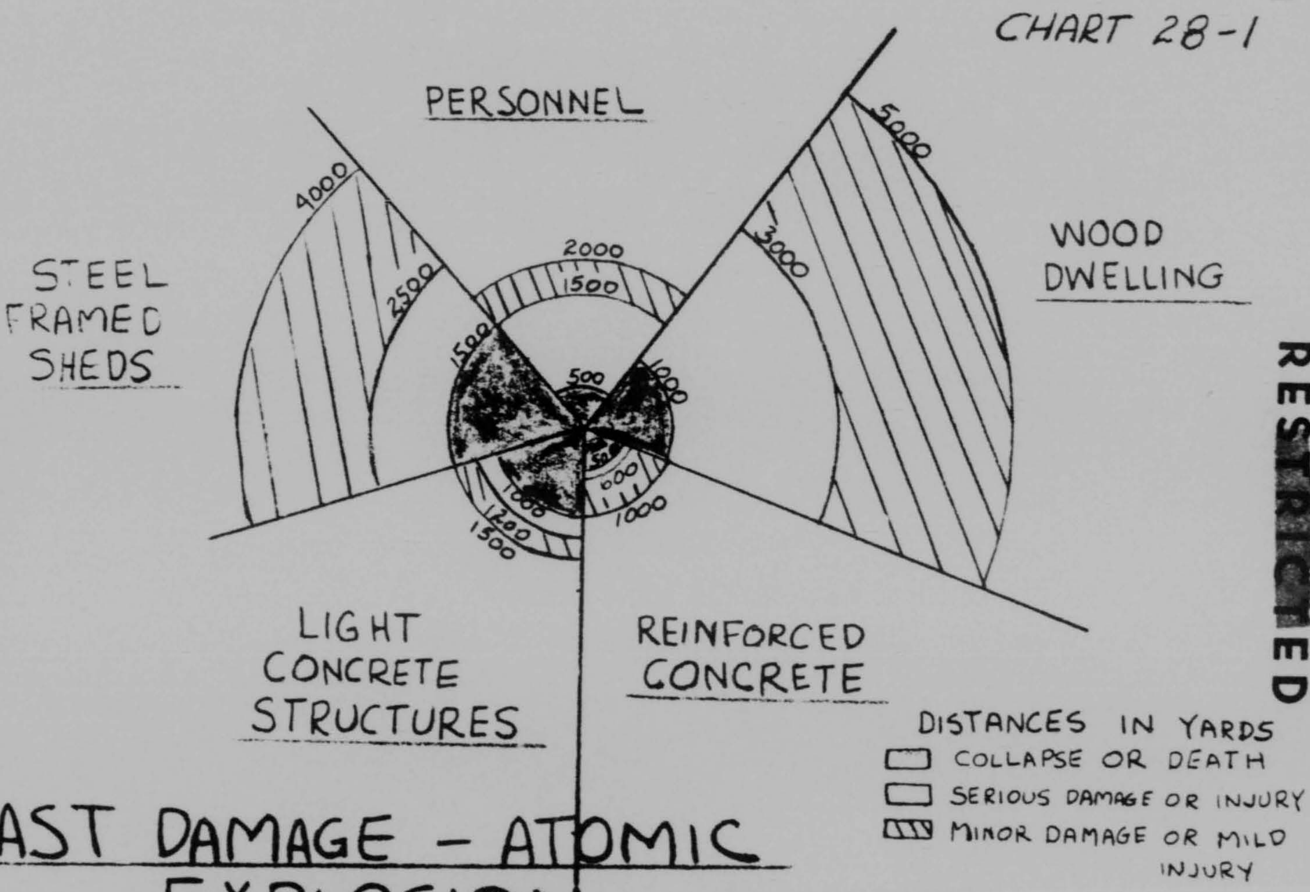

BLAST DAMAGE - ATOMIC EXPLOSION

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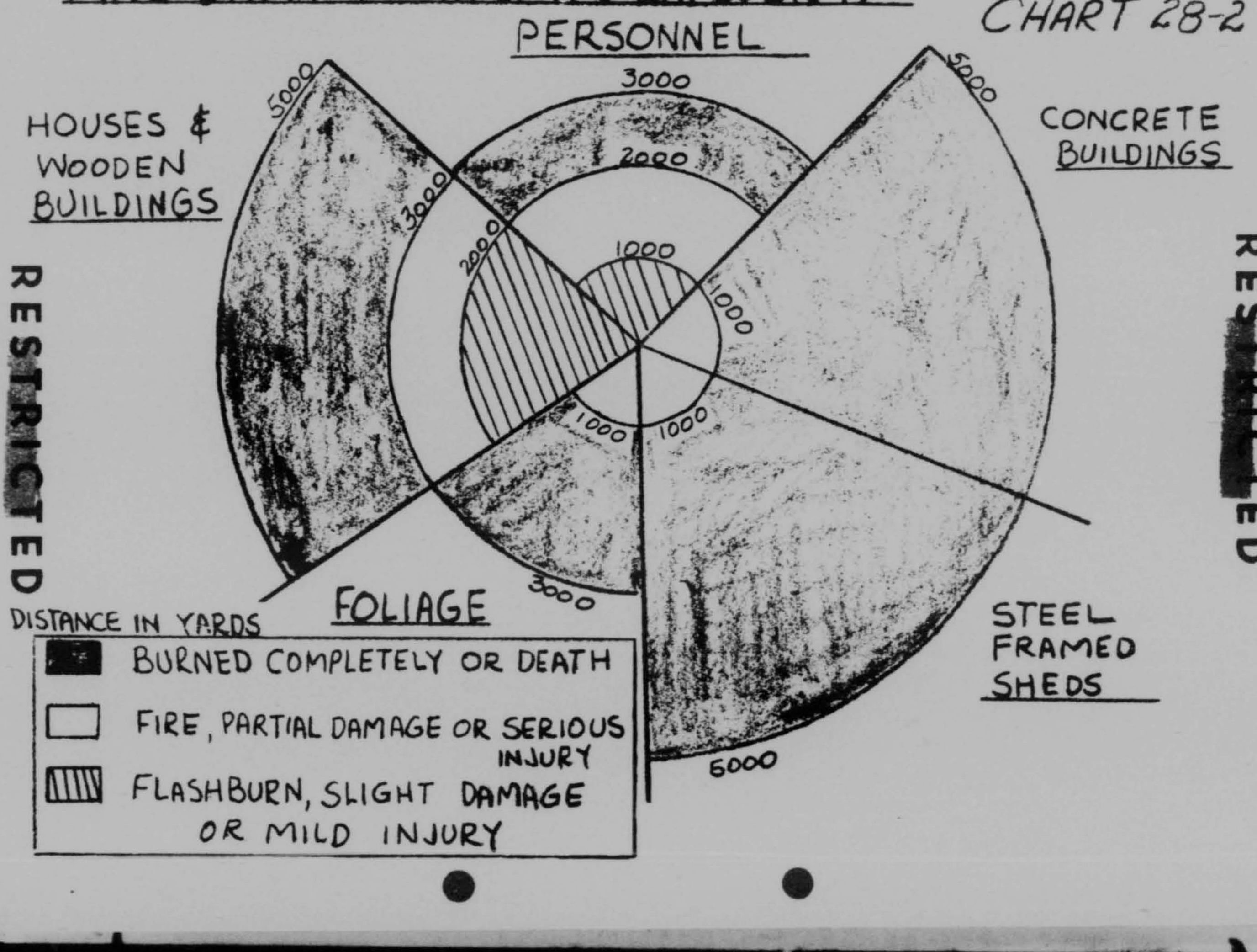
FIRE DAMAGE – ATOMIC EXPLOSION

CHART 28-2



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TRAINING OUTLINE NO:	29
LECTURE:	Atomic Bomb Explosion - Effects on an American City.
TIME:	Fifty (50) minutes.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	None. (See Footnote*)
STUDENTS' REFERENCES:	None.
TRAINING AIDS REQUIRED:	Charts appended hereto.

1. Introduction. It is important that one appreciate the real power of an atom bomb, and the purpose of this article is to present a realistic picture of the damage which a typical American city might suffer were an atom bomb to be detonated over it. As a typical city, "City X", is an excellent choice. Furthermore, it is strategically situated in the industrial heart of the United States so that it would certainly be selected as a target city if this country were ever to be embroiled in another war.

2. The Problem.

a. Just how would an aggressor nation go about atom-bombing "City X"? What type of bomb would it select? At what point would the bomb be detonated? To answer these questions one has to consider many factors.

b. The type of atomic bomb used would depend upon the technical ability of the aggressor to fabricate and detonate bigger and better bombs. Or perhaps they should be termed bigger and worse bombs. Assuming that

*This lecture is a copy of a document, prepared by Dr. R. E. Lapp of the War Department General Staff. It does not contain classified material. The charts appended hereto should be prepared beforehand on a blackboard and "blown up" as much as possible.

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the technical difficulties are surmounted and that it is possible to make A-bombs of considerably more than 20,000 tons high-explosive equivalent, than the problem of the selection of the bomb size involves a careful evaluation of the following two factors:

(1) How much of the aggressor nation's plutonium (or other fissionable material) reserve could be allocated to the target? This question brings out an interesting fact with which many may not yet be familar. The world is no longer on the gold standard; it is actually on a plutonium standard. Aggressor nations will measure their wealth in terms of the amount of fissionable material (plutonium) which they stock-pile.

(2) What is the military priority of the target? The answer to this question will involve a detailed study of the contribution which the city makes to the nation's war economy.

c. A glance at the map of "City X" shows that there are at least two areas of prime military importance. One is the "Section A" steel industry and the other is the "Section B" industrial section. Of paramount importance, but not so easily seen on a map, is the wide diversification of feeder industries which abound in the city.

3. A New Bombing Problem.

a. It will be noted that the two critical areas singled out for discussion are separated by about ten miles. In planning an ordinary bombing raid, it would be a simple problem merely to assign so many bombs to each area in the city, but in using atomic bombs, the problem is more complex. Because the A-bomb has such enormous destructive effect, one has to balance desired damage to structures against desired damage to personnel.

b. It is quite possible that in bombing "City X" it would be decided to use a detonation designed to kill off or injure the maximum number of people in the city and thus cripple the industrial capacity of the entire area. In order to knock out both "Section A" and "Section B" areas with one bomb, the bomb would have to be prohibitively large in size in comparison with the military priority of the targets. Furthermore, the use of more than one atomic bomb would not be feasible since destruction of both areas would not result in sufficient casualties in the crowded residential areas of the city.

4. Point Zero.

a. Without going into a further detailed study of the problem let it be assumed that it is decided to detonate an atomic bomb

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of 50,000 tons high explosive equivalent at an altitude of 2500 feet at Point Zero.

b. The reason for selecting the target center at Point Zero is that this will insure that the destructive effect of the bomb will not be wasted over unpopulated or non-critical areas.

c. If "City X" is situated on the shores of a lake or is so located that its build-up area fans out radially to the northeast, as much as 50% of the bomb's destructive power could be wasted over the uninhabited south western area by exploding the bomb two miles to the south west of Point Zero.

d. If one wanted to kill off large number of the population and render the city uninhabitable, one might conceivably detonate the bomb in the nearby lake. While no blast damage would be inflicted on the city, it might happen that under proper conditions the prevailing winds would carry lethal quantities of spray-borne radioactive materials over the city, thus raining down upon it lethal quantities of invisible radioactivity.

e. Why select a bomb of 50,000 H. E. equivalent? This is done to insure that the destructive range of the explosion will be sufficient to accomplish the objective of killing or maiming the maximum number of people in the area.

f. Such a bomb would be more than twice as powerful (published value = 20,000 tons H. E. equivalent) as the type used on Nagasaki. Without violating any security regulations, it is possible to say a few things about the bomb mechanism. Despite all of its differences from an ordinary explosive, the atomic bomb has at least one similarity. Under proper conditions, an increase in the amount of charge (fissionable material such as plutonium) can result in a corresponding increase in the over-all explosive power of the bomb.

5. Possible Size Limitations.

a. However, since the trick in setting off atomic explosives is to keep the fissionable parts in a subcritical state until the time desired for detonation, it is obvious that making more powerful bombs of the Nagasaki type will require considerable development. The reason for this is, that if one assumes that two subcritical masses of plutonium are violently brought together (made critical), then using the same technique more than two such subcritical masses must likewise be brought together if a higher order explosion is desired; this is easier said than done. Furthermore there is no guarantee that when one successfully detonates such an improved atom bomb, it will have the same

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efficiency per pound of plutonium as obtained with a smaller bomb. In view of the scarcity of this man-made element, it must be carefully rationed in peace and in war.

b. These two factors might alone limit the ultimate feasible size for atom bombs but there is another even more convincing reason why plutonium bombs may not be progressively increased in destructive power. This reason, simply stated, is that one 20,000-ton high explosive blast does not do as much direct damage as two 10,000-ton explosions. This rule holds true for all explosives.

6. Altitude of Detonation.

a. How does one decide at what altitude the bomb should be exploded and why are these bombs exploded so high in the air? The exact altitude for detonation depends upon the explosive power of the bomb, the nature of the target, and the type of damage desired over the given area. If one wants to annihilate a small but vitally-important installation, the proper procedure is to explode the bomb as close as possible to the target. But if the damage is to be extended over a much greater flat area, then one simply explodes the bomb high enough in the air so that the blast wave will extend out over the desired area and still produce destructive effects.

b. At Nagasaki, where the Japanese tell us the bomb exploded 1800 feet above the ground, there were about ten square miles of land hard hit by the blast. At Almogordo, N. M., the bomb was only 100 feet above the ground and less than three square miles were damaged to the same degree.

7. The Attack.

a. With the foregoing facts in mind, one can proceed to examine what would happen to the "City X" if it were subjected to an atom bombing of the type just described. Let us assume the attack takes place at noon when the downtown area is most heavily populated.

b. The city is enjoying a pleasant sunny day with a cooling breeze coming in. The streets are thronged with thousands of shoppers in the downtown and Point Zero areas. Then suddenly and without warning the bomb is detonated high above the city.

c. A dazzling bluish-white flash blinds those people on nearby streets and sears them at the same time with its million-degree heat. Almost within a thousandth of a second the small ball of fire shoots out to form a sphere of flame 100 yards in radius. Simultaneously the color of the ball changes going over to a varicolored seething mass which spreads outward and downward at terrifying speed. Above it all, a huge pinkish white mushroom "atomic cloud" forms and climbs toward the stratosphere.

d. Directly under the blast, the instantaneous flash of heat sears all pedestrians into unidentifiable charred and grotesque forms. Those shielded from the heat are momentarily conscious of a terrible pressure wave that topples taller buildings and crumbles others into rubble. Within a second a blast wind of near supersonic velocity rushes in and demolishes those buildings untouched by the primary blast wave. The air is thick with dust from pulverized buildings and the crashing of surrounding buildings creates a din which is soon followed by the ominous Niagara-like noise of fires ignited by the flash.

8. Secondary Damage.

a. To feed the multitude of fires, air rushes in from the surrounding area, even overcoming the prevailing breeze, and soon a firestorm of gale proportions sweeps the city. This unusual fire-storm persists for several hours and makes the entire area near the epicenter inaccessible to what fire-fighting equipment is available. Streets made impassable with debris, the failure of the water pressure, disrupted communications all prevent fire fighters from reaching the stricken area.

b. Within a three-mile radius of the epicenter, the number of dead and injured is staggering to the imagination. Those who were with-in one mile of the blash center, while still surviving, are living on borrowed time. When the brilliant flash of light occurred, those living within a mile of the blast center were exposed to a deadly dose of penetrating radiation. Unseen, unheard and unfelt these deadly rays penetrated the human tissue and left their mark. Perhaps the survivors would linger for a few days, or even a few weeks but they are doomed.

c. Much of the enormous damage is due not so much to the primary effect of the bomb but to the secondary effects. In this cat-egory, one would list fire damage, injuries due to collapse of the fire-gutted buildings, deaths from burns, suffocation and lack of med-ical care. Much of the effectiveness of the A-bomb is due to its in-stantaneous and widespread action. A modern and efficient fire depart-ment, such as "City X" has, can cope capably with a few outbreaks of fire within the city, but when hundreds of fires are simultaneously started miles apart in an impassable area, it is a hopeless task to stem the onrush of the holocaust.

9. Damage at Point Zero.

a. Suppose that the fire burns itself out within the next day and one can then re-enter the area and critically examine the smolder-ing ruins and evaluate the over-all damage to the area. To make the survey more systematic, let the examination be concerned first with blast damage.

(INSTRUCTOR - REPRODUCE CHART 29-1)

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b. In the larger map, the various zones of damage due to blast are outlined. Since it is difficult to separate the individual effect of the shock wave from that of the blast wind, their combined effect is considered. From the epicenter to a distance of 1 mile there is heavy blast damage. All frame and brick buildings are demolished and only those sturdy, reinforced-concrete structures on the periphery of this zone escape complete destruction. Within the zone the interior of all buildings is subject to intensive damage.

c. Both the downtown and the Point Zero shopping centers on the periphery of this zone sustain extensive damage ranging from total destruction to heavy damage. In some cases the walls of the buildings remain standing but the roofs and floors are missing. Able street is a scene of utter desolation. From the City Hall to Baker Street it is impassable. Streetcars and automobiles, many with their occupants lying dead inside them, stand out in the rubble-strewn streets.

10. Damage 1 Mile from Point Zero.

a. Farther out from the epicenter, within the 1- to 2-mile radius, heavy damage is sustained. Included within this zone is the downtown area of the city. Here some of the larger, well-built structures seem to be intact but closer examination shows that their interiors are extensively damaged and many are gutted by fire. At the lower end of Main Street, the beautiful Memorial Auditorium is in ruins, but many of the buildings along Main Street even closer to the epicenter are almost untouched. Apparently these were shielded by other buildings or merely escaped blast damage by virtue of having been "skipped".

b. The neon beacon high atop the Charles Building has been ripped asunder and lies in the street below. The main structure remains more or less intact with greatest damage being apparent on the upper part of the building. In spite of the appearance of the exterior of the modern structure, there were many casualties in it and due to the fires which raged throughout the downtown area it was impossible to evacuate all of the occupants of the building.

c. To the east, the Central Terminal still stands, but severely damaged. Without any shielding from the blast wave, parts of the structure collapsed. The railroad yards are inoperable with twisted rails jutting up from the ground. Apparently many of the railroad ties in the bed were burned by the flash.

11. Damage at a Distance.

a. Between 2 and 3 miles distance from the epicenter moderate blast damage is evidenced among the ruins. The majority of the blast damage is concentrated on frame dwellings and plants of light construction.

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Brick houses in this zone still stand but show some signs of interior damage.

b. More than 3 miles from the point of bomb detonation there are still signs of blast damage but for the most part they are minor and are masked by damage from fire.

c. It is possible for blast effects to be felt at as great a distance as 8 miles from the epicenter, but such damage would be slight and rare.

12. Fire Damage.

(INSTRUCTOR - REPRODUCE CHART 29-2)

a. When the bomb explodes a vast quantity of radiant energy (light) is liberated in the form of ultraviolet, visible and infra-red radiation. This radiation causes intense surface heating of all objects which it strikes within a 3-mile radius of the epicenter. In some cases, depending on the local conditions, this surface heating is sufficient to ignite the material. Thus, within a circle roughly 6 miles across, there may be hundreds or even thousands of fires started and of these several hundred will persist and spread.

b. The effect of such intense burning over such a wide area is to cause a mass influx of air from outside the region. This movement continues if it overcomes the prevailing winds and an enormously destructive firestorm results and whole areas untouched by the blast are burned out.

c. In "City X" the prevailing southwesterly wind would overcome the firestorm after a few hours and tend to sweep the blaze into the B Section of the city. To the north, Forest Lawn and Dog Park would act as natural fire breaks and to the southwest, the South Park section would be shielded by the prevailing winds.

13. Effects of Radioactivity.

a. Before continuing the discussion of the damage inflicted by the bombing, it is useful to summarize here certain facts which are known for radioactivity resulting from atomic-bomb-explosions. When Hiroshima and Nagasaki were A-bombed, there was great confusion in the nation about the effects of radioactivity resulting from these explosions. Some of this confusion persists today and the following facts may clarify the situation:

(1) Before the bomb is exploded the material gives off only alpha rays which are easily absorbed in a piece

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of writing paper. Except for the fact that plutonium is extremely toxic one might treat this material very casually by merely wearing gloves to protect against alpha rays. After the bomb is properly exploded, what plutonium is not "burned" up or fissioned is widely scattered and will persist for many years.

(2) When the bomb explodes, an instantaneous burst of neutrons and gamma rays occurs. These penetrating rays flash through the atmosphere and many go right through concrete walls to pass through the bodies of people inside the buildings. A thick shield of lead or many feet of earth or concrete would protect against most of the gamma rays but lead, for example, would be quite transparent to the neutrons. Except for the ground directly below the point of detonation, good protection would be afforded from the deadly radiation by a fairly deep tunnel shelter.

(3) After the bomb has exploded, the only danger that persists is from the so-called fission products which fall out from the atomic cloud and from radioactivity induced in material close to where the bomb is detonated. The fall of radioactive material from the atomic cloud depends on atmospheric conditions and it may occur over the city or it may occur many miles from the city. Such radioactivity is due to burned-out atoms (fission products) and it is composed of beta and gamma rays. Beta rays are essentially high-speed electrons and they can be absorbed in a few sheets of thin aluminum. Gamma rays, on the other hand, are extremely penetrating X-rays and require several inches of lead to filter them out. Both rays are dangerous to human tissue. Perhaps the beta rays are the most insidious for they are more difficult to measure than gamma rays and therefore are sometimes overlooked even when present. No neutrons are present after the first few seconds of the blast.

(4) Should the bomb be exploded close to the ground or to tall buildings, then considerable radioactivity is produced in this material by the action of the neutrons in passing through it. Such radioactivity is said to be "induced" in the material. Certain elements such as sodium (as in table salt) are easily made radioactive. Each element so activated by neutrons thereafter "decays" by emitting beta and gamma rays; the time taken by the various elements to decay varies from elements

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to element. Depending on the exact circumstances of the bombing, the ground below the point of detonation will be radioactive for a length of time varying up to several months' duration. For example, if an atomic bomb were smuggled into the basement of the City Hall and then detonated, it would be many weeks before that area could be safely re-entered and many months or even years before it was safe for rehabilitation.

(5) Using radioactive materials which accumulate in the manufacture of plutonium, it would be possible to make a lethal gas of finely dispersed fission-products which could be deposited on an unsuspecting city. Such a radioactive gas attack on a city would panic the entire populace unless the city were provided with radiation-measuring instruments to detect the activity. Even the rumor of such an attack would send a city's populace into flight if it were not reassured by on-the-spot instruments capable of measuring the radioactivity. Incidentally, there are very few such instruments now in "City X" and fewer still which can measure alpha rays.

(6) It should be emphasized that one cannot rely on the senses to detect the presence of radioactivity. Neutrons, beta and gamma rays can be present in lethal intensities without any immediate effect on the senses. To be sure, after a while there is a decided effect noted by the body but by that time it is too late for the victim to get away from the radiation. Scientists do not understand the ways in which penetrating radiation produces changes in human tissues, but they know what happens to such tissues after it is exposed to radiation. As a result of exposure to intense radioactivity, certain physiological changes take place in the body. Symptoms of radiation damage include nausea, vomiting, general debility, sustained fever, loss of body hair, erythema (redness of the skin from capillary congestion), loss of appetite, and a decrease in the while blood cell count. These symptoms may appear soon after the exposure or in a few weeks. For example, epilation (loss of hair) may occur within a few days or within a few weeks. Exposure to radiation accompanied by injury from burns or falling debris may result in the death of a person even though neither the radiation injury nor the burn would of itself have caused death. There is very little that medical science can do for persons suffering from radiation damage and almost nothing it can do if the victim is exposed to more than a certain critical dose of the rays.

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14. Zones of Damage from Radioactivity.

a. To return to discussion of hypothetical A-bombing of "City X", the necessary facts about radioactivity have been presented and the specific radiation damage inflicted upon the populace can now be considered.

(INSTRUCTOR - REPRODUCE CHART 29-3)

b. All persons living within a radius of about 1 1/3 miles of the epicenter would be exposed to a lethal dose of radiation provided they were not shielded by thick brick or concrete walls. A wood frame wall offers little shielding from this radiation. Therefore most of the people surviving the combined effects of fire and blast in this area would probably die within a few days or weeks from the effects of the penetrating radiation.

c. Those living in the zone from 1 1/3 miles to 2 miles from the epicenter, while not receiving a lethal dose of radiation, would receive a considerable exposure that would complicate their recovery if they suffered any other injuries. Many would show obvious signs of radiation damage, such as loss of hair, but they would later recover and live apparently normal lives.

d. Outside the 2-mile radius, there would be no effect from the primary flash of radiation, but it is possible that a fall-out of radioactivity would occur. If so, varying intensities of radioactivity might be found ranging from harmless to dangerous amounts.

e. Village Y would lie directly in the favored path of the fall-out and if conditions were such that a rain storm occurred carrying down vast quantities of radioactivity with it, then the entire populace of Village Y and surrounding territory would have to be quickly evacuated.

f. It will be recalled that in the case of the New Mexico atom-bomb test, some of the atomic cloud settled out miles away from the detonation point and cattle in the path of this fall-out latter were found to have white backs where some of the radioactive particles adhered.

15. Total Casualties.

a. In summing up the supposed atom-bombing of "City X", one can most readily realize the terrific striking power of the new weapon by estimating the total casualties caused by the explosion -- about 100,000. Of these, about 50,000 would result in fatalities. The number of fatalities would run as high as this because of the lack of proper medical facilities at the time they are needed most, i. e., the day of the explosion. At Hiroshima there were only a few hospitals in usable

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condition out of about 50. Of 1780 nurses only about 100 were available for duty after the explosion.

b. The staggering figure of 100,000 casualties would mean that every family in the city would be directly affected by the explosion. Many civic leaders, key industrialists, and thousands of skilled craftsmen would succumb to the disaster. Thus while the Section A steel plants would still be intact and outlying factories would be undamaged, the city would require many months before it could rebuild the bombed-out area, replace personnel, and repair public service throughout the striken community. "City X" would have been effectively knocked out by one bomb!

16. Defense Against Atomic Attack.

a. There are many who will ask if there is not a means of counteracting the atom bomb. The atom bomb is a new type of high explosive and as such it is the same as any other high explosive in that you can protect against it only by deflecting it from its trajectory or by blowing it apart before it reaches its object. There is no mysterious mechanism in the bomb that one can detonate prematurely by radio waves, ultrosonics, or other means.

b. The use of guided missiles may do much to enable one to seek out and explode atom bombs before they reach their objectives, but it is difficult to conceive of this process being perfected to the point where it will guarantee that no bombs will get through the defense.

c. Furthermore, since warfare of the future promises to be one of split-second timing in which the element of surprise will be of paramount importance, adequate defense would require constant on-the-trigger vigilance by every nation. In an atomic war, if even a few minutes are required for alerting defensive forces or for getting administrative decisions, the war may be over before the defense went into action.

d. The danger of insidious warfare using sabotage with radioactive materials planting atomic bombs in cities or harbors is not to be minimized.

e. This discussion is not entirely academic, for other nations will soon have atom bombs of their own. If a great world power is willing to spend enormous amounts of money, resources and manpower in an all-out effort, it may be able to produce bombs of effective design within 15 years perhaps in less than 10. This nation has already released a large amount of information about the atomic bomb which will considerably reduce the time required for another nation to make it.

f. It is true that it would require more than 10 years for another nation to duplicate our effort in atomic research on the bomb but it would profit by our experience and not try to duplicate all of it.

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g. There are many preventive measures a city can undertake to minimize damage from atom-bombs, for example, decentralization of vital facilities and utilities, proper city planning with adequate allowance for fire lanes and fire-breaks to minimize fire-damage. The building of strong reinforced concrete structures for vital industries, construction of tunnel shelters, and many other measures will all tend to make a target city less desirable as a target.

h. In many cases, the cost of such defensive measures would be prohibitive and in the final analysis, they are futile. In the few years which are left before other nations have atom bombs of their own, it is useless as well as economically unsound to try to convert our cities into decentralized underground strongholds. The effect that such action would have upon civilian morale cannot be estimated.

i. In spite of the enormous destructive power of the atomic bomb, the new weapon is not an absolute weapon. It remains to be seen just what place the weapon will have in military strategy. From the standpoint of this nation's defense, it is not at all certain that our military position is strengthened by the possession of atomic bombs. If one coldly analyzes the use to which these bombs can be put in time of war and one considers that other nations will have the same type of weapons, then it is apparent that our military position is actually weakened by the possession of the bomb. There is also a very real danger that we will delude ourselves into thinking that the atom bomb has given us military superiority over all other nations.

j. The purpose of this article has been to present various facts about the destructive power of the atomic bomb in realistic terms. It is hoped that on so doing, it has served to stimulate common sense thinking about the bomb. It is, of course, quite apparent that the answer to the threat of the atomic bomb must be found in the political, not military field. All the forces which we possess must be marshalled in a concerted effort to outlaw war as a means of settling international disputes.

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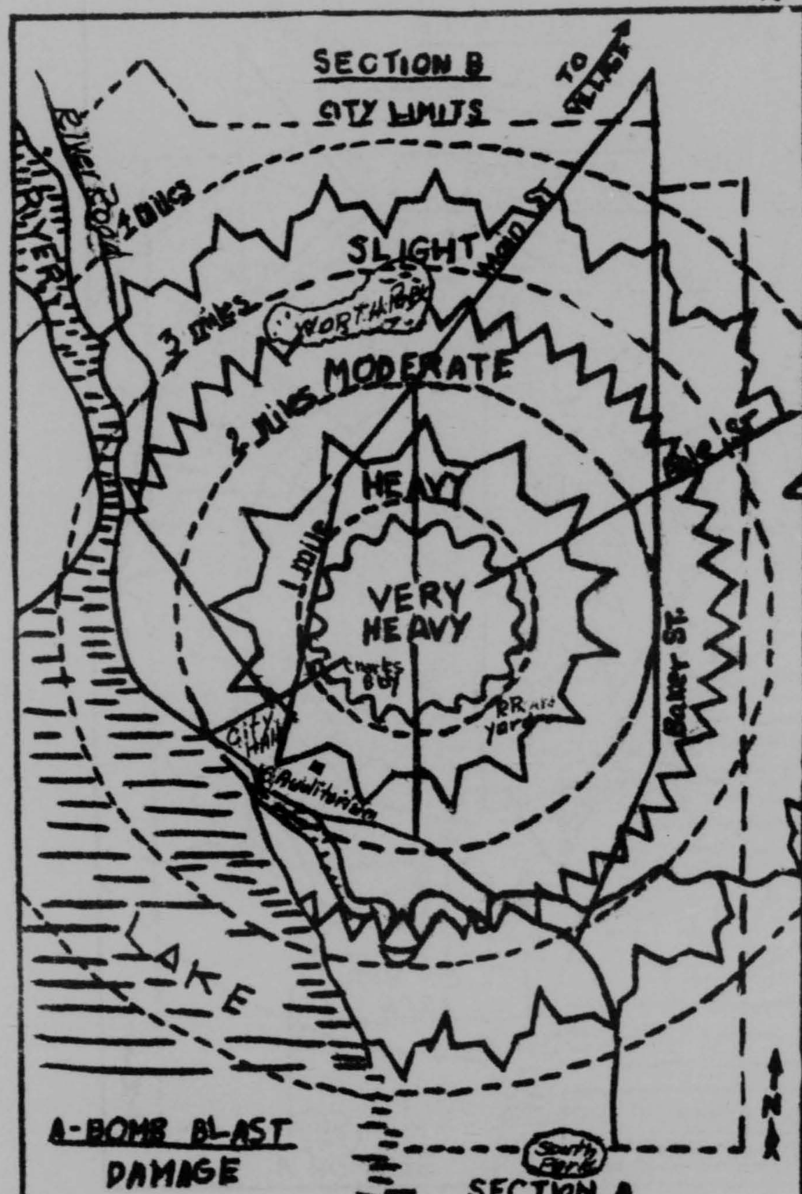

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CHART 29-2

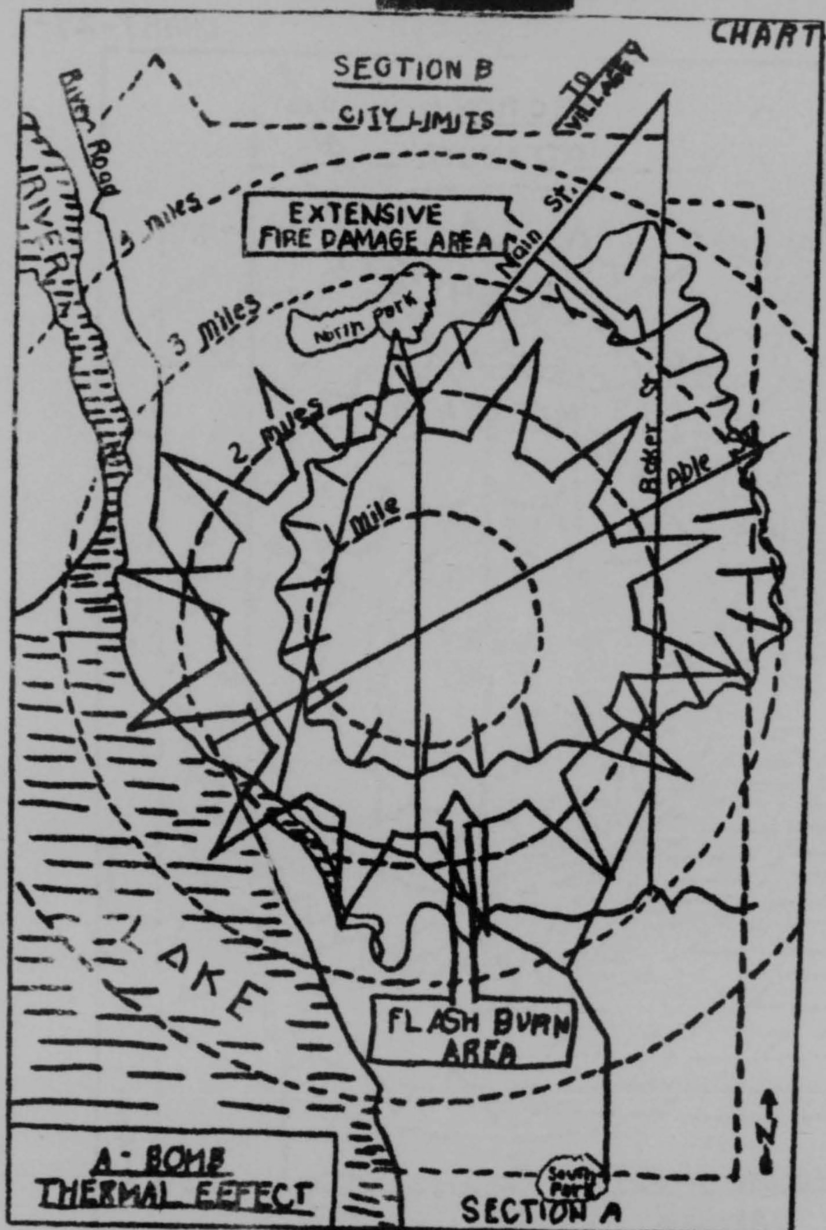
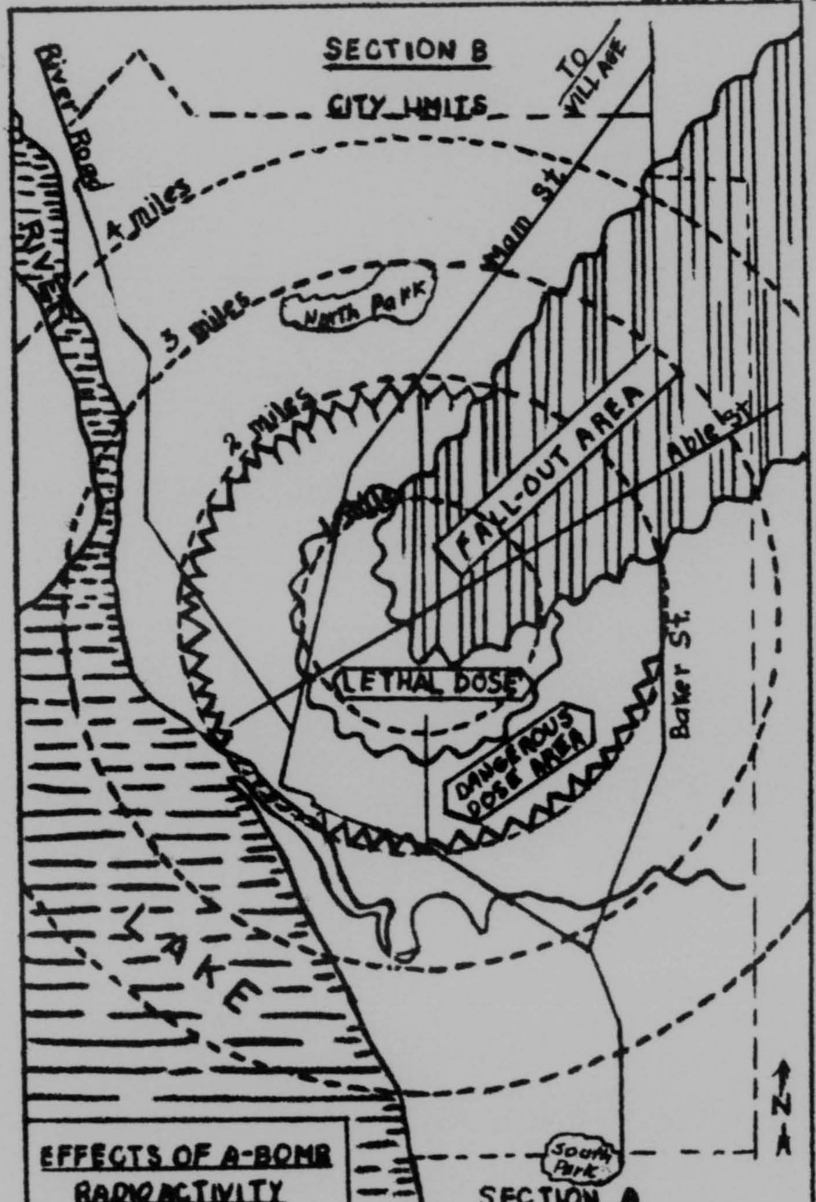

SECTION B
CITY LIMITS
River Road
RIVER
To VILLAGE
EXTENSIVE
FIRE DAMAGE AREA
Main St.
3 miles
3 miles
North Park
2 miles
Baker St.
Able
mile
LAKE
FLASH BURN
AREA
A-BOMB
THERMAL EFFECT
South Park
SECTION A
N

CHART 29-3



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TRAINING OUTLINE NO: 30

LECTURE: Seminar. General Review.

TIME: One (1) hour.

PLACE: Classroom.

INSTRUCTORS' REFERENCES: All previous material.

STUDENTS' REFERENCES: All previous material.

TRAINING AIDS REQUIRED: Blackboard.

This is intended as a question and answer period, with students asking the questions. If considered advisable, all instructors may be present, each to deal with questions pertaining to his specialty.

When no more questions from the students are forthcoming, instructors may ask questions from a previously prepared list, so organized as to provide a review for the final examination. Many or most of the questions on the final can be discussed at this point, and every attempt should be made to insure that all students have an adequate grasp of all points under discussion.

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TRAINING OUTLINE NO: 31

EXAMINATION: II

TIME: One hundred (100) minutes.

PLACE: Classroom.

INSTRUCTORS' REFERENCES: Training Outlines No 16 to 30. All previous references, Instructors's Answer Guide, (See Footnote *).

STUDENTS' REFERENCES: Lecture notes from Training Outlines No 16 to 30.

TRAINING AIDS REQUIRED: Copies of Examination II.

Instructions.

1. Use of student's notes is permissible.

2. All questions can be answered in one short sentence or less.

3. Check your paper for completeness - there are 20 questions in this examination.

QUESTIONS.

1. Is the 263A survey meter calibrated with the beta shield open or shut?

____

2. There are three intensity ranges on the 263A survey meter. What is the approximate range of each?

a. ____________ mr/hr b. ______________ mr/hr

c. ____________ mr/hr

*Students should be permitted to use their notes. At completion of examination, the questions should be reviewed and the correct answers given.

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3. The 247A survey meter has four intensity ranges. What is the range of each?

a. x1 range ________mr/hr   b. x10 range __________mr/hr

c. x100 range ______mr/hr   d. x1000 range ________mr/hr

4. How may beta radiation be measured with a 247A Survey Meter?

____

____

5. There are three checks to be made on a 247A survey meter before it is ready for operation. What are these three checks?

a. ____

b. ____

c. ____

6. Personnel entering radioactive areas wear dosimeters in addition to carrying survey meters. Why is this necessary?

____

____

7. Give two reasons why film badges are used in addition to dosimeters.

a. ____

b. ____

8. What is the significance of a 0.1 R/Day isodose line?

____

____

9. What materials are required to decontaminate personnel who have been working in radioactive areas?

____

10. Above what radiation intensity are personnel considered contaminated? __________________mr/hr. Is this gamma only or beta plus gamma? ___________________________.

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11. After an atomic explosion, the affected areas are monitored. What type of survey is made first?

____

12. Does a fox-hole afford any protection against an atomic explosion (not directly overhead)?

____

____

13. List 10 factors which should be considered in preparing a unit radiological defense plan.

a. _______________ b. _______________

c. _______________ d. _______________

e. _______________ f. _______________

g. _______________ h. _______________

i. _______________ j. _______________

14. List three cases where decontamination of radioactive contamination is possible.

a. ______________________________

b. ______________________________

c. ______________________________

15. Clothing which is worn in radioactive areas becomes contaminated. Above what intensity should it be discarded for use? __________ mr/hr

16. Casualties from an atomic explosion are due to three main causes. What are these three causes?

a. ______________________________

b. ______________________________

c. ______________________________

17. The blast effect from an atomic explosion has a definite radius. What is the radius for:

[redacted]

a. Total destruction? ________________ yards

b. Considerable damage? ______________ miles

c. Negligible damage? ________________ miles

18. What causes the majority of fires following an atomic explosion?

____

____

19. Personnel within a certain distance of an atomic explosion will receive a dose of instantaneous radiation. What is the effect at:

a. Less than 1 mile? ___________________________________

____

b. Between 1 and 1.5 miles? ____________________________

____

c. Over two miles? ______________________________________

____

20. State whether you now feel qualified to act as a unit radiological defense officer. ____

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TRAINING OUTLINE NO:	32
LECTURE:	Administrative Time.
TIME:	Fifty (50) minutes.
PLACE:	Classroom.
INSTRUCTORS' REFERENCES:	None.
STUDENTS' REFERENCES:	None.
TRAINING AIDS REQUIRED:	None.

This period is allotted for use by the officer in charge of the school. If it is possible to complete the grading of all students' work and present certificates of proficiency prior to departure, this period may be utilized to do so.

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Instructors' Answer Guide

This answer outline has been prepared for the instructors' convenience. It contains answers to all examinations and questions which are given in the training outlines.

It should be understood that a great many questions do not have one dogmatic answer. Judgment should be exercised, therefore, in the use of this guide, particularly on examinations.

Training Outline No 1

No questions.

Training Outline No 2

No questions.

Training Outline No 3

1. A molecule is the smallest portion of a compound which can exist and still be that compound. Atoms are the particles from which molecules are built.

2. Neutrons, protons and electrons.

3. Isotopes are atoms with the same number of protons in their nucleus but with different numbers of neutrons in their nucleus.

4. The significance of $E = mc^2$ is the fact that mass and energy are interconvertable.

5. A nucleus weighs 1% less than it should because 1% of the mass has been converted into binding energy.

6. Atomic energy is "released" binding energy.

Training Outline No 4

1. Energy is the ability to do work.

2. Wave lengths.

3 The shortness of wave length.

[redacted]

[redacted]

4. X-Rays.

5. High energy radiation is any ionizing radiation which contains enough energy to cause bodily harm.

6. Alpha, beta, gamma, and neutrons.

7. Gamma - greatest. Alpha - least.

Training Outline No 5

1. a. Nucleus splits into two parts.

   b. Three neutrons are liberated.

   c. Large amount of energy is released.

2. The scarity of raw material.

3. Plutonium must be made to conserve available uranium ore.

4. No, because of the critical mass factor.

5. A critical mass is the smallest amount of fissionable material which will sustain a chain reaction.

6. Increases its explosive power.

7. a. Simple neutron capture.

   b. Neutron capture with particle emission.

Training Outline No 6

1. Much greater intensity and travels faster.

2. Alpha, beta, electro-magnetic and neutron radiation.

3. About one mile.

4. a. Neutron-induced isotopes.

   b. Fission products.

   c. Unfissioned bomb material.

5. Surface heating of surrounding areas.

[redacted]

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[redacted]

6. Fall-out is the phenomena wherein radioactive material, carried away from the area by winds, eventually falls to earth miles from an explosion.

<u>Training Outline No 7</u>

1. First, second and third degree flash burns.

2. Destroys cells in the body.

3. a. Outside the body - none.

   b. Inside the body - produces cancerous growths.

4. Similar to gamma - lesser degree.

5. 0.1 R/Day.

6. External hazards are those which can cause harm while outside the body. Internal hazards are those which can cause harm only when inside the body.

<u>Training Outline No 8</u>

No questions.

<u>Training Outline No 9</u>

1. 379
2. 3809
3. 2,594,488
4. 35,742,056
5. 72.56(50)
6. 189
7. 41.5
8. 2.26
9. 62.33(7)
10. 1762
11. 508.78(66)
12. 796,936
13. 55.170,906
14. 6.53(60)
15. .079(146)
16. .00064(428)
17. 29.90(91)
18. .000081
19. 3298.307(727)
20. 2
21. 17
22. 57.58
23. 89.03
24. .0019
25. .32
26. 8.21

[redacted]

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[redacted]

Training Outline No 10

Decay Calculations Using Chart 10-3 Form

Chart 10-3 Step No.	Explosion #1	Explosion #2
Step 1	100 R/Day	400 R/Day
Step 2	1 Day	1 Day
Step 3	35.3 R/Day	100 R/Day
Step 4	2 Days	2 Days
Step 5	100/35.3 = 2.84	400/100 = 4
Step 6	0.453	0.602
Step 7	2/1 = 2	2/1 = 2
Step 8	0.301	0.301
Step 9	.453/.301 = 1.51	.602/301 = 2.0
Step 10	(Assume) 0.1 R/Day	(Assume) 0.1 R/Day
Step 11	35.3/0.1 = 353	100/0.1 = 1000
Step 12	2.547	3.000
Step 13	0.301	0.301
Step 14	0.301 x 1.51 = .455	0.301 x 2.0 = 0.602
Step 15	2.547 + .455 = 3.002	3.000 + .602 = 3.602
Step 16	3.002/1.51 = 1.91	3.602/2 = 1.801
Step 17	81.2 Days	= 63.3 Days

Training Outline No 11

No questions.

Training Outline No 12

No questions.

Training Outline No 13

1. Gamma only radiation and gamma plus beta radiation.

2. About 20 mr/hr (.48 R/Day).

3. Measurement of ionization produced in gases by high energy radiation passing through the gases.

4. Gamma only radiation.

5. Ion chambers are more accurate because they measure total ionization produced, whereas geiger counters count ionizing events.

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[redacted]

6. Up to several hundred R/Day.

Training Outline No 14

1. Beta and gamma radiation.

2. a. 0.2 - 0 to 0.2 mr/hr.

   b. 2 - 0 to 2 mr/hr.

   c. 20 - 0 to 20 mr/hr.

3. Background count is the ionization produced by cosmic radiation which is heard as a clicking noise in the headphones or a geiger counter.

4. Probe is held up to a strong light with the beta shield open. Any sudden increase in background count indicates light sensitivity.

5. By use of beta shield.

6. a. Decide intensity which is desired.

   b. Using a source, place meter at a point where the desired intensity is obtained.

   c. Listen to signal in headphones and become accustomed to the noise level and pulse repetition rate.

   d. Move probe back and forth from sample. Notice viariations in audio signal.

   e. Close your eyes and have someone move sample a short distance.

   f. Try to determine the proper point where the desired intensity exists. When this is possible within 10% error, it is possible to run an audio survey.

Training Outline No 15 (Exam I)

1. Atoms of the same element but of different weights.

2. a. Electrons

   b. Neutrons

   c. Protons

[redacted]

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[redacted]

3. Number of protons in nucleus.

4. It is the source of atomic energy (release of binding energy).

5. Any ionizing radiation which contains enough energy to cause bodily harm.

6. They have different wave lengths.

7. a. Alpha

b. Beta

c. Electro-magnetic Radiation

d. Neutrons

8. Radioactivity or radioactive decay.

9. Ionization is a process wherein orbital electrons are ejected by incident radiation.

10. Changes within the nucleus of an atom.

11. a. Liberation of energy.

b. Ejection of three neutrons.

c. Nucleus splits into two fragments.

12. a. Simple neutron capture.

b. Neutron capture with particle emission.

13. The smallest mass of fissionable material which can sustain a chain reaction.

14. a. Unfissioned bomb material.

b. Fission products.

c. Neutron-induced isotopes.

15. Fall-out is the process wherein air-borne contamination falls to earth miles from an explosion.

16. a. Blast

b. Heat

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[redacted]

c. High-energy radiation.

17. 0.1 R/Day

18. Calculating probable rate of decay of radioactive contamination.

19. To obtain reproducable readings with any radiation detection instrument.

20. $I = CM/D^2 = \frac{(.024)\ (256.00)}{(10)^2}$

$= 6.14$ R/Day

21. Beta and Gamma radiation.

22. 20 mr/hr.

23. Measure the amount of ionization produced in a gas by incident radiation.

24. Gamma radiation only.

25. Decay Calculation

Chart 10-3 Form Step No.	Calculations		
1			200 R/Day
2			1 Day
3			9 R/Day
4			12 Days
5	200/9	=	22.2
6			1.346
7	12/1	=	12
8			1.079
9	1.346/1.079	=	1.25
10	(Assume)		0.3 R/Day
11	9/0.3	=	30
12			1.477
13			1.079
14	1.079 x 1.25	=	1.350
15	1.477+ 1.350	=	2.827
16	2.827/1.25	=	2.26
17			182 Days (about six months after explosion)

[redacted]

[redacted]

Training Outline #16

No questions.

Training Outline #17

1. Gamma radiation.

2. a. x1 - 0 to 2.5 Mr/hr.

   b. x10 - 0 to 25 Mr/hr.

   c. x100 - 0 to 250 Mr/hr.

   d. x1000 - 0 to 2500 Mr/hr.

3. x1 range

4. Not possible.

5. Zero adjustment.

6. If stop pins are sheared, the instrument will not operate.

Training Outline #18

No questions.

Training Outline #19

1. Radiation intensity concerns the rate with which radiation is being emitted, while radiation dosage concerns quantities.

2. Pocket dosimeters and film badges.

3. A small ionization chamber.

4. An external charging source.

5. Less than 2 Mr/hr.

6. As a permanent legal record of beta and gamma dosage received.

7. To know at any time what dosage we have received.

8. To distinguish between beta and gamma radiation.

Training Outline #20

1. Monitoring is a continued check of the surroundings of an individual or unit in order to detect the presence of radioactivity.

[redacted]

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[redacted]

2. Lines which connect points of equal radiation intensity

3. a. The 4-5 mr/hr isodose line defines an area outside of which men can work without restrictions.

b. The 12-15 mr/hr isodose line defines an area outside of which men may work up to 8 hours per day.

4. Start using ion-chamber instruments.

5. Indicates that decay will be fairly rapid and that unfissioned bomb material is present as a hazard.

6. By use of the equation

$$It^n = K.$$

7. Evasive monitoring and survey monitoring.

8. a. Eating

b. Smoking

c. Drinking

9. 0.2 mr/hr (beta plus gamma).

<u>Training Outline No 21</u>

No questions.

<u>Training Outline No 22</u>

1. Bootees are canvas foot coverings which should be used to prevent contamination of shoes.

2. 3 mr/hr (beta plus gamma)

3. Hair, face, hands, fingernails

4. Keep contaminated personnel and equipment out of clean areas.

5. Over 0.2 mr/hr (beta plus gamma).

6. Soap, water and scrub-brush.

7. Mixture of gunk (1 part) and kerosene (9 parts) sprayed on with an M3A2 decontaminating apparatus.

[redacted]

[redacted]

8. Only by hosing down.

<u>Training Outline No 23</u>

No questions.

<u>Training Outline No 24</u>

No questions.

<u>Training Outline No 25</u>

No questions.

<u>Training Outline No 26</u>

The following material contains only the key point involved in each question:

1. Casualties from a dusted area would take longer to appear since lower radiation intensities would exist and there would be no other source of casualties.

2. a. Battle of the Bulge.

b. Pearl Harbor.

c. Corregidor.

d. Several others.

3. Radioactive agents can be made much more cheaply, easily and rapidly than atomic bombs.

4. a. Security aspects are paramount.

b. Short half-life isotopes cannot be stored for long periods. Protection of personnel handling this material is a problem.

5. a. Target surrounded by land containing strategic industries, strategic supplies or very high population densities.

b. Areas adjacent to water containing population targets or naval concentrations.

c. Land areas containing population targets.

6. Sound assumptions can be made as to probable type and extent of atomic attack.

[redacted]

[redacted]

7. a. New York City
   b. Washington, D.C.
   c. Cleveland
   d. Philadelphia
   e. Los Angeles
   f. (Other variations are likely)

8. Problematical.

Training Outline No 27

No questions.

Training Outline No 28

1. Radiation Injury - 15 - 20%
   Burns - 20 - 30%
   Secondary Injuries - 50 - 60%

2. It will be completely destroyed.

3. Up to three miles.

4. Up to two miles.

5. Up to 1.5 miles.

Training Outline No 29

No questions.

Training Outline No 30

No questions.

Training Outline No 31

1. Shut.

2. a. 0 - 0.2 mr/hr.
   b. 0 - 2.0 mr/hr.
   c. 0 - 20 mr/hr.

[redacted]

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[redacted]

3. a. x1 - 0 to 2.5 mr/hr
   b. x10 - 0 to 25 mr/hr
   c. x100 - 0 to 250 mr/hr
   d. x1000 - 0 to 2500 mr/hr

4. It cannot.

5. a. Battery check.

   b. Sensitivity check.

   c. Zero check.

6. To readily ascertain what radiation dosage they have received.

7. a. Permanent legal record.

   b. Distinguish between beta and gamma radiation.

8. Areas outside this line are not restricted.

9. Soap, water and scrub-brushes.

10. 0.2 mr/hr (beta plus gamma).

11. Hasty survey.

12. Yes.

13. a. Responsibility
    b. Organization
    c. Training
    d. Warning System
    e. Personnel Decontamination
    f. Shelters
    g. Monitoring
    h. Communications
    i. Supply
    j. Fall-out areas
    k. Civilian Aspects
    l. Materiel Decontamination
    m. Medical
    n. Special Instructions

14. a. Personnel.

    b. Critical items of equipment.

    c. Very small areas.

15. 3.0 mr/hr (beta plus gamma)

16. a. Flash burns.

    b. Radiation injury.

    c. Secondary injuries.

[redacted]

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[redacted]

17. a. 1000 yards.

    b. Three miles.

    c. Six miles.

18. Secondary causes such as shorts, stoves, process fires, fuel storage tanks.

19. a. Fatal.

    b. Serious injury.

    c. Little effect.

20. Answer depends on student's reaction.

[redacted]

CONAC MANUAL 125 - 2

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April 1949

CRIMINAL INVESTIGATION

OFFICE OF THE PROVOST MARSHAL

CONTINENTAL AIR COMMAND

5-2260-12

APRIL 1949

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FOREWORD

1. This manual was prepared by Lt Colonel Clifford V. Oje Sr., Office of Provost Marshal, Headquarters Continental Air Command, Mitchel Air Force Base, New York, and is published for the information and guidance of personnel assigned to the Provost Marshal activity who are required to make investigations of crimes and offenses during their tour of duty.

2. With the establishment of the Office of Special Investigations, a centrally directed investigative service was provided for the United States Air Force. As a result, some confusion and uncertainty has developed regarding the investigative functions of Provost Marshals. This manual was written specifically to clarify and delineate the residual investigative responsibilities of the Provost Marshal activity.

3. This publication should be issued to each Air Force Policeman as a manual for reference and study.

A. E. TANNER
Lt Colonel, USAF
Provost Marshal
Continental Air Command

5-2260-12

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SECTION I - GENERAL

1. Purpose of Manual.

a. This manual is intended to be used as a ready reference and guide by Air Force Policemen and other interested personnel in the investigation, prevention and suppression of crime and military offenses.

b. It is anticipated that the information and suggestions embodied herein will clarify the responsibility of Air Force Policemen in the field of criminal investigation. Cognizance has been taken of the important role of the newly organized Office of Special Investigations under The Inspector General in the investigation of major crimes. There has been no attempt to infringe on the prerogatives and requirements that have been established for the OSI in the fulfillment of their mission in criminal investigation. On the contrary, it is the intent of this manual to provide procedures for Air Force Policemen in which they will better be enabled to assist and cooperate with the OSI and at the same time, assume their own responsibilities in the investigation of crime.

c. It is further hoped that this manual will assist in the standardization of investigative procedures that come within the purview of the Provost Marshal activity.

d. It is not the purpose of this manual to discuss and portray every detail necessary in the investigation of crime. Detailed criminal investigative techniques will be found in other military manuals and publications. Particular reference is made to FM 19-20, "Criminal Investigation".

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2. Responsibility.

a. Regardless of the availability of the services of the OSI, commanders will continue to make inquiry into all matters which adversely affect the efficiency, morale or welfare of their commands. (See par. 5c, AFL 20-4)

b. The Provost Marshals will still assume the responsibility for the investigation, prevention and suppression of all minor crimes and offenses.

c. Air Force Policemen (MOS 677) will supplement their duties by making investigations of those cases that come within the purview of the Provost Marshal activity.

SECTION II - FUNCTIONS

3. Functions. The functions of the Provost Marshal in the investigation of crimes and military offenses are governed by the following:

a. The complete investigation of certain minor crimes and offenses.

b. The preliminary investigation of major crimes and subsequent necessary action prior to transfer of such cases to the OSI.

c. The transfer of such cases to the OSI that deal with major crimes, those that require investigation in locations not contiguous to the local Air Force base and such other complicated and complex cases that warrant the attention of highly trained investigative technicians.

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d. The completion of necessary action upon the return of a completed case from the OSI.

e. The establishment of oral or written agreements with the OSI on necessary administrative details.

f. The maintenance of a roster of individuals engaged in investigative activities with whom coordination and cooperation are necessary.

g. The preparation and maintenance of a local up-to-date standing operating procedure for the investigation of crimes and military offenses.

h. The clarification and interpretation of existing policies, directives and publications pertaining to the criminal investigative responsibilities within the Provost Marshal activity.

i. The proper supervision and control of all investigative matters.

j. The preparation of reports and the maintenance of records of all investigative cases.

k. The provision for adequate training in criminal investigations through the medium of interim Provost Marshal training, on-the-job experience and attendance at The Military Police School.

l. The preparation of reports for the commander of all investigative cases that are completed or referred to the OSI.

m. The preparation of reports for the commander that will indicate trends and patterns of conduct, discipline and incidents of crime.

n. Initiation of procedures and methods for the prevention and suppression of crime.

o. Ascertain that proper standards of military discipline are in effect in each unit on the base.

p. Establishment of coordination with proper agencies on the base to insure adequate provision for those factors that provide for good welfare and morale among the airmen.

q. The maintenance of an esprit de corps between the Air Force Policemen and other airmen.

SECTION III - ADMINISTRATION

4. Personnel.

a. Assignment.

(1) Criminal investigative sections or branches will not be organized or designated as a part of the organization of the Provost Marshal activity.

(2) Air Force Policemen will be assigned to investigative duties who have had the most experience and training in such activities.

(3) Before an Air Force Policeman is assigned full responsibility for investigating any case, he should have had some specialized training in investigative techniques and should have been assigned to investigative details with other experienced and trained Air Force Policemen for at least sixty days.

(4) An Air Force Policeman who has been assigned to investigative duties should possess an unusual aptitude for investigative work but should not have

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"cloak and dagger" leanings.

(5) Air Force Policemen performing investigative duties will not be known as investigator, agent, Mister, or detective. They will be known only as Air Force Policemen.

(6) Air Force Policemen should be extended every opportunity to display their ability and to learn techniques incident to investigations. All personnel of the Air Police who are assigned to an MOS of 677 should be potential investigators. The best men should be considered when called upon to make nominations to fill vacancies in the OSI.

(7) A criminal investigator, MOS 301, is not authorized for investigative duties in the Provost Marshal activity.

b. Qualifications. In the assignment and selection of Air Force Policemen for investigative duties, consideration should be given to the following criteria:

(1) Investigative experience in civilian and military life.

(2) Airmen who formerly possessed an MOS No. 301 and who were not transferred to the OSI - providing there are no pertinent reasons which barred them from being satisfactory investigators.

(3) Graduate of the Special Investigator's Course at The Military Police School.

(4) Legal training and experience.

(5) Civilian police training and experience.

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(6) A natural leaning to and reasoning power for investigative activities.

(7) A graduate from high school.

(8) An AGCT score of 110 or more.

(9) A character rating of "Excellent" and is known to possess temperate habits.

(10) Has not been convicted of a felony by either a military or a civilian court.

(11) Possesses an MOS No. 677.

(12) Has served at least sixty days as an assistant to an Air Force Policeman assigned to investigative duties.

(13) Air Force Policemen engaged in investigative activities must be tactful and courteous; must understand the duties and responsibilities involved in the Provost Marshal activity; must possess a working knowledge of all regulations and directives pertinent to criminal investigations; must have knowledge of essential handweapons; must possess a personal dignity and be serious and conscientious; must not be patronizing, demanding, boastful or egotistical; and must possess an everlasting industry and a wholesome proportion of common sense.

5. <u>Credentials</u>.

a. No special identification cards, badges or credentials will be provided Air Force Policemen engaged in investigative activities. The brassard will remain the symbol of authority and the

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official means of identification of all Air Force Policemen.

6. Uniforms.

a. Air Force Policemen engaged in investigative duties will wear the identical uniform prescribed for Air Force Policemen. Civilian clothes will not be worn at any time during the official investigation of any case. Concealed weapons will not be carried. The .45 caliber pistol or revolver is authorized for use by Air Force Policemen in their official duties.

7. Incidental Expenses.

a. No special project funds have been authorized for Air Force Policemen engaged in investigative assignments other than those allotted to the regular Provost Marshal activity.

b. Commutation of rations and quarters are not authorized for investigative duties. When an investigation of a case requires that investigation be made at a distance from the base, necessitating additional travel, personal expenses and overnight delays, the entire case or that phase of the investigation requiring travel will be transferred or turned over to the OSI.

8. Transportation.

a. Ordinary transportation facilities available to the Provost Marshal activity will be used. The use of civilian vehicles is not authorized for investigative assignments.

9. Supply and Equipment.

a. The equipment and supplies for investigative activities is authorized in T/A 1-1, "Equipment for Air Force", and T/O & E 1-8014, "Air Police Squadrons", and T/O & E 1-0001A.

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10. Training.

a. Criminal investigative techniques will be taught to all Air Force Policemen in special interim training classes provided for Air Police Squadrons. A long-range program of technical criminal investigative subjects should be devised.

(1) The following list of subjects will serve as a guide in the preparation of a course of study in criminal investigations:

Articles of War	Report Writing
Interrogations	Statements and Confessions
Interviews	Crime Prevention
Arrests	Fingerprinting
Searches and Seizures	Casting and Molding
Sources of Information	Firearms Identification
Observation and Description	Preservation and Handling of Evidence
Allied Investigative Agencies	Expert Testimony
Notes and Sketches	Crime Scene Searches
Investigative Photography	

b. Problems that arise from the investigation of criminal cases should be made a matter of discussion and study at special training periods set aside for the Air Police Squadrons.

c. All Air Force Policemen should be provided with on-the-job training conducted by experienced investigators.

d. Arrangements should be made for the outstanding Air Force Policemen within each Air Police Squadron to attend The Military Police School. Quotas should be submitted in accordance with existing directives on the subject.

SECTION IV - FUNCTIONS AND RESPONSIBILITIES OF THE OSI

11. **Responsibilities and Functions.**

a. Specific functions and responsibilities of the OSI are outlined in paragraph 5, AF Letter 20-4, AF Letter 124-3 and AF Letter 124-4, as follows:

(1) Establishment of a competent and centrally directed special investigative service to all Air Force activities.

(2) The availability of trained investigative specialists and technicians to perform all types of investigations for commanders when required or requested by them.

(3) Submission of interim or progress reports to commanders advising them of the activity on a current basis.

(4) Forward completed reports of investigation to the interested commanders for appropriate action.

(5) Apprise commanders of trends and patterns of irregularities and offenses as disclosed by a centralized operation to commanders.

(6) The establishment of procedures for the investigation of all major offenses including fraud and conspiracy, major crimes of arson, black market operations, bribery, burglary, embezzlement, forgery, larceny involving more than $50.00, perjury, robbery, smuggling and such other major

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violations of the Articles of War and federal statute as come within the purview of the OSI.

(7) The detection and investigation of espionage, sabotage, treason, sedition, subversion, disloyalty and disaffection.

(8) Investigation of violations of AR 380-5 and personnel backgrounds and loyalty checks.

(9) The summarization and analysis of information regarding the status and extent of disaffection, subversion, espionage and sabotage, and the dissemination of this information to appropriate Air Force agencies and commanders.

SECTION V - TYPICAL CASES WITHIN THE PURVIEW OF THE PROVOST MARSHAL

12. Typical Cases.

a. A great majority of crimes committed in the military services are minor crimes, and thereby warrant investigation by the Office of the Provost Marshal. Typical cases in which Air Force Policemen will assume the responsibility for making complete investigations are indicated by the following:

(1) AWOL and desertion.

NOTE: When an AWOL or desertion case is involved in a major crime, or when the investigation necessitates overnight travel and additional expenses, they will be transferred in part or in toto to the OSI, except when the case is assigned to apprehension teams.

(2) Straggling, malingering and misbehaving before the enemy.

(3) Improper use of a countersign or forcing a safeguard.

(4) Fraudulent reenlistment, false muster, false returns or false pretenses.

(5) Escape, attempt, or conspiracy to escape.

(6) Releasing prisoners without proper authority, or failure to report the commitment of a prisoner to a commander.

(7) Misbehavior of a sentinel or guard.

(8) Conduct - bringing disrespect to the military service, or conduct unbecoming an officer or a gentleman.

(9) Disrespect or disobedience toward superiors.

(10) Violations of local rules and regulations.

(11) Drunkenness.

(12) Failure to pay debts or failure to keep promises to pay debts.

(13) Larceny less than $50.00 in value.

(14) Minor cases of arson or mayhem.

(15) Violations of regulations regarding captured property.

(16) Vehicle accidents - involving a government vehicle where negligence may have been the cause for an accident or where a claim may be made against the government.

NOTE: When the facilities of the Provost Marshal are inadequate for the proper investigation and handling of any of the above offenses, the Provost Marshal will solicit the cooperation and assistance of the OSI. It might be necessary in some instances to transfer entire cases to the OSI.

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Offenses in which an officer is the offender or subject will be investigated personally by the Provost Marshal at the base concerned.

b. Normally, Air Force Policemen will be the first law enforcement agency to arrive at a scene of crime. It will be compulsory for them in every case to take the necessary action to insure that all preliminary details will be resolved in their initial investigation. If it is found that the investigation is a case for the OSI, the crime scene will be left intact in as far as possible. Proper security will be provided in such cases, arrests will be made as warranted and the OSI will be notified immediately.

SECTION VI - OPERATIONAL PROCEDURES

13. General.

a. The operational procedures as outlined and described in this section do not represent a complete study of the operational techniques employed in criminal investigative activities. Many textbooks and publications have been written on the operational procedures involved in criminal investigations. Particular attention is called to FM 19-20, "Criminal Investigation" and the syllabi prepared by The Military Police School on criminal investigations.

b. While this manual is not intended to cover every detail necessary in the operation of a criminal investigative program, it will serve as a reminder of the many fundamental operational details which might easily escape the attention of our Air Force Policemen in their investigation of crime.

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14. Making Initial Investigation.

a. When an Air Force Policeman discovers a crime or a violation of military rules or regulations, he will take immediate action as follows:

(1) Take such steps as are necessary in the protection of human life and government or civilian property.

(2) Arrest offenders, when warranted.

(3) Record initial statements of witnesses and suspects.

(4) Insure that the crime scene remains intact until such time as proper pictures are taken and a crime sketch is made.

NOTES: In the case of a murder, it is necessary that no one touch or move the body, that none of the physical properties in the vicinity of the murdered person be disturbed until such time as a crime sketch is made and adequate pictures are taken.

In case of suspected suicide, the person, if dead, should not be taken down if he is hanging. The surrounding physical properties should not be moved until a crime sketch has been made and proper pictures have been taken.

(5) Sketch and photograph the scene of crime.

(6) Immediately notify your superior upon the discovery of any crime.

(7) Assimilate all data and information.

(8) Take necessary steps to prevent any further criminal action or violation of military rules or regulations at the scene of crime.

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b. Preliminary investigations by Air Force Policemen are justified in certain major cases where the OSI are not immediately available and where the conduct of the investigation will suffer.

(1) Furthermore, cases at first might appear to be minor crimes but after initial investigation may assume the proportions of major crimes that necessitate investigation by the OSI.

15. <u>Taking Subsequent Action</u>.

a. Upon completion of initial action, the Provost Marshal will determine whether or not the case warrants investigation by the OSI.

b. If it is determined that the case warrants further action by the OSI, the Provost Marshal will take such steps as have been previously arranged by verbal or written agreement with the OSI and transfer the case with all pertinent data to the proper district office of the OSI.

(1) In some cases, it will be necessary to review the case with the commanding officer in order to determine whether or not the case should be transferred to the OSI for investigation.

c. Immediately upon the transfer of a case to the OSI, the Provost Marshal will notify the commanding officer of the action taken.

(1) A special file will be maintained by the Provost Marshal on all cases transferred or referred to the OSI. A copy will be filed of correspondence in all cases that are transferred to the OSI.

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d. Cases that require action by the Provost Marshal will be completed by Air Force Policemen who are designated by the Provost Marshal.

e. Upon receipt of completed cases that are returned from the OSI, necessary action by the Provost Marshal will be taken as follows:

(1) Immediately report the return of the case to the commanding officer.

(2) When warranted, discuss further possible action with the commanding officer and the legal officer.

(3) Process case to the subject's immediate commanding officer for prosecution.

(4) Confine suspects, when warranted.

(5) Insure that necessary charge sheets are prepared by subject's immediate commanding officer.

(6) Request the commanding officer responsible for the preparation of charges notify the Provost Marshal of completed action including results of trial. Close out the case and file under completed OSI cases.

(7) Notify OSI of completed action in order that case may be closed in their files.

f. Prepare adequate reports on all cases.

16. Reporting Incidents to Superiors.

a. Upon the discovery of a crime either through observation or by report, the immediate superior in command available at the time will be notified without delay.

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(1) This report will include a brief estimate of the situation and incorporate the details outlined in the suggested form in Appendix II.

b. Provost Marshals will keep commanding officers informed on incidents of major importance.

17. Supervising Investigations.

a. Provost Marshals will maintain close supervision and control over all those investigative activities that come within the purview of their offices.

b. All incidents will be carefully screened by Provost Marshals to ascertain that all cases have been transferred to the OSI that require their attention.

c. Investigations will be conducted in accordance with military standards as provided in FM 19-20 and other pertinent directives. Provost Marshals will supervise the inspection techniques to ascertain that they comply with existing policies and procedures.

18. Preparing Reports.

a. The fundamentals and procedures of writing reports as described in Chapter 14, FM 19-20 and amplified herein will be observed in making written reports on the results of investigations.

(1) Before writing a report, the Air Force Policeman should read the Courts-Martial Manual to determine what type of crime the report covers and what proofs are necessary to render a conviction.

b. The standard report forms WD AGO 19-65, 19-66, will be employed in making written reports of completed investigative cases.

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(1) The provisions of paragraph 7a and b(1), and paragraph 8, AR 380-5, 15 August 1946 will cover the classification of reports.

(2) Care will be exercised to insure that reports of investigations are not overclassified.

c. Provost Marshals will review investigative reports to the extent necessary to insure that desirable standards of investigative procedures are maintained and that all possible clues have been uncovered and that the maximum development of such clues has been executed.

(1) When warranted, they will initiate necessary action to correct deficiences or irregularities in investigative procedures.

d. Reports of investigative activities required by this and higher headquarters will conform to instructions published from time to time.

(1) Directives governing such reports in existence as of the date of this manual are:

(a) ConAC Letter 37-2, "Reports of Offenses and Criminal Investigative Activities", 9 April 1947, as amended.

(b) ConAC Letter 37-3, "Flash Report of Serious Crimes", 14 May 1947.

e. Air Force Policemen should always take notes preparatory to writing a report.

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NOTES: A good set of notes is a prerequisite to a good report. Anything worth remembering is worth writing down. A report is a word-picture of an investigation conducted.

(1) Every good set of notes must answer the five basic questions:

(a) Who?
(b) What?
(c) How?
(d) Where?
(e) When?

(2) Notes must be:

(a) Neutral.
(b) Definite.
(c) Clear.
(d) Concise.
(e) Brief.
(f) Free of superfluous words.

(3) The date on the notes should be the calendar date when the notes were actually taken. Pages should be numbered and titles given to the pages. Initial all notes.

(4) Personal opinions should not be included in notes.

(5) Divulge information only to or through superiors. Never discuss promiscuously any information on any case.

(6) Report things as they are actually found, not as you would like them to be or as you think they should be or might be.

(a) Do not adopt the statement of an informant as your own. It might be wrong.

f. The five cardinal principles essential in the preparation of a report include the following:

(1) Accuracy.

(2) Completeness.

(3) Brevity.

(4) Fairness.

(5) Clarity and arrangement.

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19. Maintaining Records.

a. Provost Marshals will maintain their own administrative records and files on all cases to meet local requirements and to the extent necessary to prepare statistics and periodic reports required by higher headquarters or by their commanding officers.

b. An adequate filing system will be established by each Provost Marshal to insure that all pertinent information, exhibits and evidence pertaining to a given case are properly assembled, to provide ready access to such material and to afford full and complete control over all such material.

20. Advising Personnel of Rights Under the 24th Article of War

a. The 5th Amendment to the Constitution of the United States provides that in a criminal case, no person shall be compelled to be a witness against himself.

(1) The principle employed in this process applies to trials by courts-martial and is not limited to the person on trial but extends to any person who may be called as a witness.

b. The use of coercion or unlawful influence in any manner whatever by any person to obtain any statement, admission or confession from any accused person or witness, shall be deemed to be conduct to the prejudice of good order and military discipline.

c. No statement, admission or confession obtained by coercion or unlawful influence will be received in evidence by any courts-martial.

d. It shall be the duty of any person in obtaining a

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statement from an accused to advise him that he does not have to make any statement at all regarding the offense of which he is accused or being investigated and that any statement made by the accused may be used as evidence against him in a trial by courts-martial.

21. Interrogating Suspects and Interviewing Witnesses.

a. In interrogating or obtaining statements from suspects or in interviewing witnesses, the use of fear, force, intimidations or threats and promises is not authorized in investigative procedures. This method of operation will not be tolerated in obtaining statements from suspects or in interrogating and interviewing witnesses and suspects.

b. In the interrogation of personnel subject to the Articles of War, the individual concerned will have his rights under the 24th Article of War fully explained to him prior to questioning in each instance.

c. In the interrogation of a civilian, his rights under the 5th Amendment to the United States Constitution will be fully explained.

(1) Whenever practicable, interrogation of civilians will be made in the presence of civilian police officers.

d. Care must be exercised to insure that practices are not indulged by Air Force Policemen that would preclude the use of written statements or the admission of confessions in courts of competent jurisdiction.

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(1) In this connection, paragraph 127, MCM, 1949, should be carefully considered.

(2) If a statement amounts to a confession, the mere recitation in the statement that the person making it was informed of his rights and the statement was voluntarily made is not sufficient to render the statement admissible as evidence upon subsequent trial of a person.

(a) If, in fact, the statement was induced by threats or promises or by subjecting the person to prolonged discomfort and such facts appear at the trial, it might not be submitted as evidence.

(b) The Supreme Court of the United States has held that the use of a confession obtained by force or fear would violate the constitutional guarantee against self-incrimination and constitutes a denial under due process of the 5th and 14th Amendments which cannot be cured by other clear evidence of guilt.

1. In such cases, regardless of the preponderance of other clear evidences of guilt, a conviction would be overruled (See Page 13, JAG Bulletin, Department of the Army, January to March 1948).

e. In addition to the procedure described in Chapter 4, FM 19-20, April 1945, the following practices will be observed in

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obtaining written statements from witnesses or suspects:

(1) The exact wording used in explaining the individual's rights will be included at the beginning of the written statement.

(2) Whenever possible, a sworn statement will be obtained.

(a) Such statement will be read, signed, witnessed by one or more persons and sworn to before a Summary Court Officer, Notary Public, or any other person, authorized to administer oaths.

(3) Statements not in the handwriting of the witness will include a phrase in the concluding paragraph to the effect that the deponent has read the foregoing or has had it read aloud to him in the presence of a person whose signature is affixed.

22. <u>Handling and Preserving Evidence</u>.

a. There are two kinds of physical evidence - fixed or immovable and removable.

(1) Fixed evidence cannot be presented in court. Fixed evidence includes such things as footprints in the soil, tire prints in the mud and anything that cannot be removed or carried from the crime scene in its entirety or as a whole.

(2) Removable evidence is that which can be picked up at the scene, properly preserved and identified and later used to assist in the solution of a case. It is material found at the crime scene

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that can be removed in its entirety.

b. The principal factors necessary in handling physical evidence includes the following:

(1) Protection. Protection is necessary to:

(a) Guard against any changes by mutilation, pollution or alteration.

(b) Maintain proper chain of custody.

(c) Minimize the possibility of examination by unauthorized persons.

(d) Maintain identity of evidence.

(2) Collection.

(a) In collecting evidence, caution should be exercised in guarding against damage or destruction in removing evidence, or danger of destruction of other evidence in the process of removal.

(b) A systematic procedure will be adopted in the collection techniques.

(c) In addition to any removable evidence that is collected, it might be necessary to collect such evidence as photographs, notes and sketches, casts and molds.

(3) Identification.

(a) The primary factor in identification is the type of articles to be identified.

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(b) Methods of identification include such items as letters, symbols, files, tags and labels.

(4) Preservation.

(a) The purpose of preserving evidence is to insure that the evidence will arrive at the laboratory or court in its original condition.

(b) A record must be kept of all personnel handling the evidence.

(c) Sealing is necessary to prevent handling or inspecting by unauthorized persons.

(d) Evidence should be stored in a safe, filing cabinet or other protective container.

(5) Evaluation.

(a) All evidence should be evaluated to eliminate nonpertinent material.

c. Laboratory Examination.

(1) Full advantage will be taken of laboratory facilities that are available in each locality for the scientific development of evidence.

(2) Many of the civilian and federal investigative agencies will furnish laboratory assistance when requested.

(3) The Criminal Investigation Laboratory at The Military Police School will furnish technical assistance provided the physical evidence is forwarded to that facility.

(a) The rules set forth in Chapter 16, FM 19-20, will be observed in handling and preparing evidence for transmittal to a laboratory.

(b) Evidence must reach the examiner with the least possible delay.

(c) The letter of transmittal will not go through channels but will be directed to The Scientific Investigation Laboratory, The Military Police School, Camp Gordon, Georgia.

(d) The body of the letter of transmittal will include the following:

Paragraph 1 - Itemized list of evidence submitted.

Paragraph 2 - Examinations desired.

Paragraph 3 - Instructions as to return or retention of evidence by the laboratory.

(e) Evidence will always be double-wrapped with a legend on the inside wrapper as follows: "Evidence Do Not Open"

23. Processing Recovered Property.

a. Accountability and adequate security will be maintained for all monies and property recovered during the course of an investigation.

(1) In the event monies or property are to be used as evidence in a criminal case, the general rules

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for the preservation of "the chain of evidence" must be observed.

(2) Closed case reports will show the distribution of recovered monies and property.

(3) Receipts for all monies and property will be maintained in the headquarters to which the investigator is assigned.

(a) Certified copies of such receipts will be attached to the closing report.

b. The following procedure will be followed in investigative activities in accounting for all recovered monies, property and other valuables including all evidence pending final disposition of the case concerned:

(1) The investigative activity will be responsible for the final disposition of all evidence and recovered monies, property and other valuables fixed as evidence by an investigative activity.

(a) Whenever possible, the signature of the person from whom the evidence is taken will also be affixed on the receipt to verify its accuracy. Three copies will be prepared, one for the files, one to be attached to the initial investigation report and one to be furnished to the person from whom the evidence is taken.

(2) When delivering evidence to an authorized prosecuting agency, a receipt will be obtained from the prosecutor

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and filed as a matter of record and for proper accountability.

(a) Upon final disposition of the case concerned, the investigative activity will repossess and deliver said evidence to its legal owner, accountable or finance officer, as applicable.

(3) When making final disposition of monies or property, the investigative activity will prepare the receipt according to the situation (Column A below), the type and number of receipts (Column B below), and make distribution of such receipts as shown in (Column C below).

__NOTE__: This latter distribution is mandatory for the investigative activity and is in addition to the distribution required to meet the needs of the supply agency or finance officer.

(A) Situation	(B) Type of Receipt	(C) Distribution
(1) Return of private property or monies.	Letter type receipt in duplicate.	1. Office of Investigative activity. 2. Final report of investigation.
(2) Return of government property to a supply agency.	WD AGO Form 447 in quadruplicate.	1. Office of Investigative activity. 2. Final report of investigation. 3. Appropriate AF Audit Agency. 4. Supply agency.

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(A) Situation	(B) Type of Receipt	(C) Distribution
(3) Return of monies to United States Treasury (through Finance Officer)	WD AGO Form 14-44 in triplicate.	1. Office of Investigative activity. 2. Final Report of investigation. 3. Appropriate AF Audit Agency.

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(4) When two or more persons claim the same property and it is not possible for the officer to determine positively the rightful owner, the disputed property will be retained and the question will be referred to the Judge Advocate. (Reference: Page 329, Digest of Opinions of TAG, 1912-40). A copy of the disposition order will be filed with the investigative activity with the record copy of the investigative report.

(5) Abandoned private property will be held until the period of time, prescribed by local laws for the recovery of personal property, has elapsed and then disposed of by the investigative activity in the manner prescribed in paragraph 35, TM 38-505.

(6) Final disposition of evidence, recovered monies, property and other valuables will be indicated in closing or final investigative report.

24. Appearing As a Witness in Court. (See Chapter 6, FM 19-20)

a. The trial of a criminal is not the responsibility of a criminal investigator. The trial is the culmination of the history of a crime. However, in order that the guilty will be convicted and the innocent acquitted at a trial, it is necessary frequently for the investigator to testify in court.

b. The investigator, when appearing as a witness in court, must conduct himself as a gentleman and be courteous and even-tempered. He must never become irritated but must answer all questions in a quiet and dignified manner but absolutely impartial in speech and action.

c. Prior to going to the court, the Air Force Policeman should review thoroughly his original notes and arrange them in logical order.

(1) The investigator has the right to consider his notes on the witness stand, if necessary to refresh his memory, before replying to questioning.

(2) Notes may be put into evidence, if they are brought into the court.

d. Important rules that must be observed by investigators for testifying in court include the following:

(1) Testimony should be given slowly and distinctly.

(2) Replies to questions should be clear and definite.

(3) Offer an opinion on a point only if requested.

(4) Avoid making conflicting or contradictory statements.

(5) All questions must be answered truthfully whether the answer be adverse or beneficial to the accused.

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(6) He must maintain an unbiased attitude.

(7) If he is unable to answer a question, the investigator should reply, "I don't know".

25. Preventing and Suppressing Crime.

a. Two factors must be co-existent before a crime can be committed, first the desire or impulse, and secondly the opportunity.

(1) Air Force Policemen should be interested in preventing and suppressing both factors.

b. Techniques and methods that may be employed in the prevention and suppression of crime include the following:

(1) Establish educational and orientational programs with all personnel on the base.

(2) Employ a system of warnings in the enforcement of rules and regulations.

(3) Establish rehabilitation programs for prisoners and offenders.

(4) Segregate hardened criminals from petty offenders.

(5) Secure the assistance of such civilian agencies as Alcoholics Anonymous for preventing serious recurrence of drunkenness.

(6) Separate undesirables from the Service.

(7) Maintain a pass system for all personnel on the base.

(8) Establish adequate security for warehouses and storage facilities.

(9) Provide adequate checks on the loading, unloading, transporting, storing of supplies and equipment, and

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for the proper handling and storage of damaged cases and supplies.

(10) Provide for an adequate number of trained Air Force Policemen in the enforcement of laws and regulations and for proper security.

(11) Restrict the use of keys and combinations to certain personnel.

(12) Provide for a periodic spot-check of all drivers entering and leaving a base.

(13) Establish "off limits" and "restricted" areas.

(14) Provide for locking public buildings during hours of non-use, such as the Officers' and NCOs' Clubs, Exchanges and Service Clubs.

(15) Ascertain that an adequate investigative procedure has been initiated on the loyalty character and background history of all personnel assigned tasks which warrant the use of classified documents and materials.

(16) Provide for the security of all valuable merchandise, equipment and supplies.

(17) Provide adequate security for valuable merchandise that is displayed in Exchanges, Officers' and NCOs' Clubs (bingo and bridge prizes) and Service Clubs.

(18) Establish proper liaison with civilian law enforcement agencies.

(19) Provide for undercover checks to apprehend pilferers.

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(20) Conduct surveys of warehouses, exchanges, supply and storage areas to reduce or eliminate the possibility of larceny and misappropriation of government food, clothing, equipment and supplies.

NOTE: These surveys are limited solely to crime prevention and the apprehension of criminals. Reasonable safeguards will be placed in effect to prevent and discourage theft.

(21) Apprise commanders of the investigative activity on a current basis by the submission of interim or progress reports of all current cases.

(22) Furnish commanders with information concerning an analysis of trends and patterns of irregularities and offenses within their commands and take such corrective action necessary to prevent and suppress crime.

SECTION VII - COOPERATION AND LIAISON WITH OTHER AGENCIES

26. Office of Special Investigation

a. Personnel of the Provost Marshal's Office will cooperate to the fullest extent with the OSI in the following:

(1) Render maximum investigative assistance when requested by the OSI.

(2) Initiate initial investigation of major crimes and offenses when the OSI are not readily available and the progress of the case will suffer.

(3) Refer cases to the OSI with all essential pertinent data and information on cases initially investigated by the Air Force Policemen that come

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within the purview of the OSI.

(4) Establish, preferably in writing, a working agreement with the OSI relative to the transfer and administration of cases in which the OSI is requested to make a partial or complete investigation.

(5) Maintain a list of investigators from the local district office of the OSI together with their addresses and telephone numbers.

27. Civilian Agencies.

a. Provost Marshals should cause proper liaison and coordination to be established with all civilian investigative agencies within their areas.

(1) An up-to-date directory of key personnel, including their telephone numbers and addresses, will be maintained.

b. Full use will be made of all pertinent allied agencies as listed in Chapter 2, FM 19-20.

28. Other Armed Services.

a. Active liaison with other Air Force commands, Army commands and Naval authorities will be established and maintained to secure the maximum cooperation in the investigation of cases that might come under their jurisdiction or in which they might render valuable assistance.

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APPENDIX I - DEFINITIONS

(A glossary of criminal phrases, terms of expression commonly used by criminals and those dealing with them is listed in Appendix II, Part I, FM 19-20, "Criminal Investigation")

Accomplice	A person who unites in or is in some way concerned in the commission of a crime for which an accused is on trial.
Admission	An incriminatory statement falling short of an acknowledgement of guilt.
Alias	An assumed name.
Allege	To state without proof.
Anthracene	An invisible powder used in apprehending thieves; it cannot be cleansed easily from any article or person touching it and can be readily seen under an ultra violet light.
Apprehend	To seize, take a person into custody.
Arson	The wilful and malicious burning of a dwelling house or outhouse of another.
Assault	The attempt or offer to do a corporal hurt to another; physical contact is not necessary in assault - merely to put the person in fear of death or bodily harm.
Attempt to Commit a Crime	An act done with specific intent to commit a particular crime and proximately tending to, but falling short of, its consummation.
Battery	The act of beating; unlawful physical constraint or violence used by one person against another without justification.
Ballistics	The science of firearms identification of bullets and cartridge cases with weapons from which they were fired.
Benzedrine Inhaler	A narcotic inhaler used to alleviate colds; also used by criminals as dope, which will either produce a stupor, sleep or great exhileration. (Pro-

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hibited in places of confinement)

Biomo-Thymol Blue	An acid used in detecting stolen gasoline.
Burglary	The breaking and entering in the night, of another person's dwelling house, with intent to commit a felony therein; a tent is not a subject of burglary.
Carnal Knowledge	The act or state of assaulting a woman by force with intent to overcome any resistance, actual or constructive, to penetrate her body; rape.
Case	A crime which authorities are investigating.
Chain of Evidence	The course thru which evidence passes from the time it is secured until it is presented in court.
Clue	A fact or hint forming the key to a solution of a problem, plot or crime.
Complainant	A plaintiff or petitioner; the one in an action or proceeding who makes a complaint against another; the defendent.
Coercion	Force, compel
Confessions	A confession is an acknowledgment in express terms by the accused in a criminal case of his guilt of the crime charged.
Contempt, Direct	An act committed in the presence of a court which interrupts the proceedings.
Contempt, Constructive or Indirect	A refusal to comply with an order of a court.
Corpus Delec-ti	The whole body of essential and fundamental facts connected with an alleged act, which make the act a crime or a breaking of the law.
Crime	Any act or omission prohibited by public law for the protection of the public and made punishable by the State in a judicial proceeding in its own name.
Crime Laboratory	A scientific laboratory for the study and examination of evidence presented in criminal cases.
Crime Scene Search	A careful, methodical, and detailed examination of all objects and conditions at the scene of a crime.

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Criminal Investigation	The art of finding and discovering the true facts of a crime and of an offense; the action necessary in determining the true identity of the perpetrator of a crime.
Criminal Investigation Division	An integral part of a law enforcement agency or a private firm responsible for the investigation of crime.
Criminal Receivers (Fences)	A person who earns a livelihood by criminally receiving and disposing of stolen goods.
Dermyl Nitrates	Paraffin test to determine whether the subject has fired a weapon.
Derogatory Information	Information which indicates disaffection or disloyalty to the Government; information of the character traits and associations of an individual which might be disqualifying as a good security risk for a position of trust.
Description	The act of giving an account of anything; a word picture.
Desertion	AWOL plus intent not to return; or AWOL to avoid hazardous duty and for important service.
Document	An original or official paper that furnishes information, proof or support of anything.
Duress	Constraint or compulsion.
Embezzlement	The fraudulent appropriation of property by a person to whom it has been intrusted and into whose hands it has lawfully come.
Evidence	That which tends to prove or disprove any matter in question; it includes all that may be submitted to a court-martial whether it be the statement of witnesses from the stand, disposition, the contents of papers, documents, or records, or the inspection by the court of whatever it may be permitted to examine during the trial.
Evidence, Direct	That which tends to show a fact or matter in issuing without intervention of proof of any other fact.
Evidence, Circumstantial	That which relates to facts other than those in issue but from which facts either alone or in connection

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with other facts, a court may, according to the common experience of mankind reasonably infer the existence or non-existence of a fact in issue.

Evidence, Opinion — Generally, a witness must state only what he has learned through his five senses as being a fact. However, on matters within the common observation and experience of men, a witness may express an opinion. A witness who is skilled in some art or trade, service, or who is peculiarily learned in some particular field may express an opinion on a state of facts that need "expert" interpretation. His qualifications as an expert should be shown to the court before he gives an opinion.

Evidence, Physical — Any article or material found in an investigation which might assist in the solution of a case.

Felony — An offense punishable by death or imprisonment for a term exceeding one year.

Fence — One who receives stolen goods; a place where stolen goods are received. (See Criminal Receivers)

Forgery — The act of making, with intent to defraud, a false or counterfeit document.

Fraudulent — Characterized by, or obtained by, unfair methods; guilty of trickery; dishonest.

Hearsay — Evidence of the existence of a fact based not on a witness's own personal knowledge or observation but on what someone said.

Housebreaking — Unlawful entering of another's building, with intent to commit a criminal offense therein.

Impeachment — Diminish credibility; an accusation.

Incarcerate — To place in prison.

Informant — Any person who willingly gives police information without any thought of gain.

Information, Source of — Any personal element of contact which furthers the progress of an investigation.

Informer — One who confidentially provides an investigator with information with thought of personal gain.

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Infra-red Photography	Photography accomplished by use of invisible light.
Interrogate	To question subject.
Interview	To question victim or witness.
Investigate	To search into by patient inquiry, observation and study of facts.
Investigative Photography	Taking of photographs which are satisfactory for an investigation, and are proof of facts.
Investigative Report	An official written record of information obtained by investigation.
Judicial Notice	Recognition by the court of certain kinds of facts that need not be proved because the court is authorized to recognize their existence without proof.
Larceny	The taking and carrying away, by trespass, of personal property which the trespasser knows to belong either generally or specially to another, with intent to deprive such owner of his property therein; as distinguished from robbery - accomplished by stealth; intent to permanently deprive owner of the use of the property taken.
Lead	A possible source of pertinent information which may contribute to the solution of a case.
Manslaughter	An unlawful homicide without malice aforethought, and is either voluntary or involuntary.
Manslaughter, Involuntary	Homicide unintentionally caused in the commission of an unlawful act not amounting to a felony; culpable negligency in performing a lawful act.
Manslaughter, Voluntary	Where the act of causing death is committed in the heat of sudden passion caused by provocation.
Mayhem	A hurt of any part of a man's body whereby he is rendered less able in fighting either to defend himself or to annoy his adversary; must be wilfully and maliciously done, but need not be premeditated.
Military Crimes	Commonly recognized civil crimes when committed by persons subject to military law are also military crimes, the punitive Articles of War 54 through 96 define various types of military offenses and crimes.

Misconduct	Implies a wrongful intention and not a mere error of judgment.
Misdemeanor	All offenses not felonies are misdemeanors.
Modus Operandi	Method of operation used by a criminal.
Motive	That which urges into action; inducement; inner reason for performing a given act.
Murder	The unlawful killing of a human being with malice aforethought; murder is not tried in military court when committed within geographical limits of the United States in time of peace; death must take place within a year and a day of the act or omission that caused it.
Negligence	The absence of due care.
Office of Special Investigation (OSI)	An investigative agency whose duty is the investigation of: the loyalty of both civilian and military personnel, contract employees and Atomic Energy Commission through National Agency checks and background investigations: major crimes and petty larceny of more than $50.00; and matters involving crime, violations of public trust, subversion and related activities within the jurisdiction of the Air Force.
Perjury	The willful and corrupt giving, upon a lawful oath, or in any form allowed by law to be substituted for an oath, in a judicial proceeding or course of justice, of false testimony material to the issue or matter of inquiry.
Perpetrate	To commit (an offense).
Perpetrator	One who commits(an offense).
Photostatic Copy	Duplicated pictures of documents and other pictures.
Pilferage	Larceny to plunder or steal; especially to steal in small amounts.
Polygraph	Commonly known as a "lie-detector" and is a combination of pneumograph which records respiration, the sphygmograph which records blood pressure, the cardiograph which records heart movement through the pulse, and the galvanograph which records the activity of sweat glands.

Portrait Parle	The art of describing a person; spoken picture or speaking likeness including description of person, personal data, physical description and general background.
Prima Facie	At the first view: as it appears on the surface.
Rape	Ravishment of a woman by force.
Report "Wrapper"	Title given report (or in blotter entry, title given blotter entry).
Report Writing	A connected word picture of an entire investigation in outline form and chronological order.
Res Gestae	Circumstances, including exclamations, declarations and statements of participants and bystanders, substantially contemporaneous with the main fact under consideration and so closely connected with the main fact as to throw light upon its character.
Robbery	The taking, with intent to steal, of personal property of another, from his person or in his presence, by violence or intimidation.
Sabotage	The willful and deliberate destruction of property, or, any conceivable act which destroys or interrupts the normal function of any person, place, or thing aiding in the war effort, or, any subversive action or omission which slows up or stops war production.
Scopolamine	A drug that produces semi-sleep and removes inhibitions. Under the influence of the drug, the subject will speak out frankly without fear of consequences of his statement. (Information received in this manner is not admissible as evidence in court).
Self-Incrimination	No person shall be compelled in any criminal case to be a witness against himself.
Sketching a Scene	A sketch made of a crime scene which shows location, approaches and entrance to building or area; size and number of rooms, location of finger-prints and footprints or tracks; objects on the floor, ceiling and walls; windows and doors opened or closed; and all other physical description to the crime.
Sodomy	Unnatural sexual intercourse between males, or of human beings with animals.

Subject	The accused or the offender in the report of a case.
Subpoena	A process (method) to cause a witness to appear and give testimony.
Suicide	The act of intentionally taking ones own life; self-murder; self-destruction.
Surveillance	The process of watching suspected persons, vehicles or premises with a view to obtaining information regarding activities, operations, associates and contacts.
Surveillant (Shadow or Tailman)	The person who performs and maintains the surveillance.
Surveillance, Moving	When the investigator actually follows subject on foot or by vehicle.
Suspect	One believed to be guilty of some crime, without having sufficient proof or evidence.
Toxicology	The science of poisons, their sources, effects, tests and antidotes.
Ultra-violet Photography	Photography under an ultra-violet light which reveals certain kinds of secret writing, invisible laundry marks, semen stains, scars and certain other invisible stains or materials.
Undercover Work	Differs from surveillance in that in undercover work the agent makes direct contact with the subject.
Unlawful	Without legal justification or excuse.
Usuary	Loaning money for interest.
Victim	Person who has suffered as a result of a violation or an infraction of law.

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APPENDIX II - INITIAL REPORT FORM
(See Par. 16)

INITIAL REPORT
OFFICE OF THE PROVOST MARSHAL

____
(Time Reported)

____
(Date Reported)

Reported by ______________________________________
(Name) (Grade) (ASN)

Unit ______________________________________

(A) Type of Incident ______________________________
(Rape, assault arson, burglary, house-breaking, etc.

(B) Time of Incident ______________ Date of Incident ______________

(C) ______________________________________
(Complete address or intersections)

(D) Personnel Involved:

____
(Name, grade, ASN, and Unit)

____
(Name, grade, ASN, and Unit)

____
(Civilian - Name and address) (Sex)

____
(Civilian - Name and address) (Sex)

(E) Details: ______________________________________
(Statement of facts and circumstances, what, who,
____
where, etc; if applicable, injuries; if hospitalized,
____
name of hospital)

* If space does not suffice, use reverse side.

(F) Action taken: ______________________________
(Include disposition of personnel, whether
____
confined, released to unit CO, etc., Agency investigating.)

(G) Source of original report ______________________
(Civilian Police, Air Police, etc.

Distribution:

____
(Signature)

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APPENDIX III - REFERENCES

1. Publications of Interest to the Provost Marshal.

a. Paragraph 5c and 6b, Air Force Letter 20-4, 19 July 1948, "Administration of District Offices of Director of Special Investigations."

b. Air Force Letter 46-13, 13 February 1948, "Report of Offenses".

c. Air Force Letter 125-6, 24 January 1949, "Criminal Investigations - Provost Marshal".

d. Continental Air Command Letter 15-22, 12 April 1948, "Report of Offenses and Criminal Investigations Activities", and amended by Continental Air Command Letter 15-22A, 27 May 1948.

e. Manual of Courts-Martial, 1 February 1949 edition.

f. Chapter VI, FM 19-5, 14 June 1944, "Military Police".

g. FM 19-20, April 1945, "Criminal Investigation".

h. TM 27-255, February 1945, "Military Justice Procedure".

i. AAF Manual 120-5 (120-0-2), June 1945, "Manual for Investigations" (Air Inspectors).

2. OSI Publications.

a. Paragraph 5, Air Force Letter 20-4, 19 July 1948, "Office of the Inspector General - USAF".

b. Air Force Letter 124-2, 19 July 1948, "Administration of District Offices of the Director of Special Investigations".

c. Air Force Letter 124-3, 13 August 1948, "Fraud Against the United States".

d. Air Force Letter 124-4, 2 September 1948, "Investigations of Civilian Employees".

e. Section I, WD Circular 276, 1946, "Criminal Investigation Program".

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Frame Number	Classification Number	Date Period	Vol.	Pt.	Title	Security Classification	Remarks
4	419.7174-2	Mar/50			Exercise Swarmer		
239	419.7174-3	Apr-May/50			|	U	
416	419.7174-4	Apr/50			|	U	
484	419.7174-5	Apr-may/50			|	U	
595	419.719-1	Apr/50			ORT Conference	U	
639	419.724-22	Mar/49			Air Reserve Officers.	U	
651	419.724-22	Feb/50			Air Reserve Officers.	U	
663	419.724-45	1948-1949			Air Force ROTC.	U	
817	419.7242050-2	Apr/49			Air Science 2.	U	
917	419.7242050-11	May/49	1		Air Armament.	U	
1130	|	May/49	2		|	U	
1257	419.724-2050-11	Jun/49	3		Air Armament.	U	
1389	419.7242050-12	Apr/49	2		AF Communications.	U	
1550	419.724205-1	Sep/49			Radiological Defense Course.	U	
1799	419.7242125-2	Apr/49			Criminal Investigation.	U	
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